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PROCEEDINGS
AND
TRANSACTIONS
OF THE
LIVERPOOL BIOLOGICAL SOCIETY.

VOL. XXIII.

SESSION 1908-1909.

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LIVERPOOL:
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1909.

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PROCEEDINGS

OF THE

LIVERPOOL BIOLOGICAL SOCIETY.

OFFICE-BEARERS AND COUNCIL.

Ex-Presidents:

1886—87 Prof. W. MITCHELL BANKS, M.D., F.R.C.S.
1887—88 J. J. DRYSDALE, M.D.
1888—89 Prof. W. A. HERDMAN, D.Sc., F.R.S.E.
1889—90 Prof. W. A. HERDMAN, D.Sc., F.R.S.E.
1890—91 T. J. MOORE, C.M.Z.S.
1891—92 T. J. MOORE, C.M.Z.S.
1892—93 ALFRED O. WALKER, J.P., F.L.S.
1893—94 JOHN NEWTON, M.R.C.S.
1894—95 Prof. F. GOTCH, M.A., F.R.S.
1895—96 Prof. R. J. HARVEY GIBSON, M.A.
1896—97 HENRY O. FORBES, LL.D., F.Z.S.
1897—98 ISAAC C. THOMPSON, F.L.S., F.R.M.S.
1898—99 Prof. C. S. SHERRINGTON, M.D., F.R.S.
1899—1900 J. WIGLESWORTH, M.D., F.R.C.P.
1900—1901 Prof. PATERSON, M.D., M.R.C.S.
1901—1902 HENRY C. BEASLEY.
1902—1903 R. CATON, M.D., F.R.C.P.
1903—1904 Rev. T. S. LEA, M.A.
1904—1905 ALFRED LEICESTER.
1905—1906 JOSEPH LOMAS, F.G.S.
1906—1907 Prof. W. A. HERDMAN, D.Sc., F.R.S.
1907—1908 W. T. HAYDON, F.L.S.

SESSION XXIII., 1908-1909.

President:

Prof. B. MOORE, M.A., D.Sc.

Vice-Presidents:

Prof. W. A. HERDMAN, D.Sc., F.R.S.
W. T. HAYDON, F.L.S.

Hon. Treasurer:

W. J. HALLS.

Hon. Librarian:

JAMES JOHNSTONE, B.Sc.

Hon. Secretary:

JOSEPH A. CLUBB, D.Sc.

Council:

HENRY C. BEASLEY.
M. CUSSANS, B.Sc. (Miss).
E. GLYNN, M.A., M.B.
OULTON HARRISON.
W. S. LAVEROCK, M.A., B.Sc.
DOUGLAS LAURIE, M.A.
J. LOMAS, F.G.S. (*deceased*)
R. NEWSTEAD, M.Sc., A.L.S.
J. H. O'CONNELL, L.R.C.P.
JOSEPH PEARSON, D.Sc.
Prof. SHERRINGTON, F.R.S.
E. THOMPSON.

Representative of Students' Section:

E. E. BILLINGTON.

REPORT of the COUNCIL.

During the Session 1908-09 there have been seven ordinary meetings and one field meeting of the Society.

The Session has been saddened by the death of two of the oldest members of the Society—Mr. Alfred Leicester and Mr. Joseph Lomas. They have both taken an active interest in the Society from its commencement, and the Council desires to record its appreciation of their services and of the great loss sustained by their death.

The communications made to the Society at the ordinary meetings have been representative of almost all branches of Biology, and the various exhibitions and demonstrations thereon have been of great interest.

By invitation of the Council, Prof. J. Arthur Thompson, M.A., of Aberdeen University, lectured before the Society, at the March Meeting, on "The Biology of the Seasons."

The Library continues to make satisfactory progress, and additional important changes have been arranged.

The Treasurer's statement and balance-sheet are appended.

The members at present on the roll are as follows:—

Ordinary members - - - - - - -	50
Associate members - - - - - - -	33
Student members, including Students' Section -	18
Total - -	101

SUMMARY of PROCEEDINGS at the MEETINGS.

The first meeting of the twenty-third session was held at the University, on Friday, October 9th, 1908.

The President-elect (Prof. B. Moore, M.A., D.Sc.) took the chair in the Zoology Theatre.

1. The Report of the Council on the Session 1907-1908 (see "Proceedings," Vol. XXII., p. viii.) was submitted and adopted.

2. The Treasurer's Balance Sheet for the Session 1907-1908 (see "Proceedings," Vol. XXII., p. xviii.) was submitted and approved.

3. The following Office-bearers and Council for the ensuing Session were elected:—Vice-Presidents, Prof. Herdman, D.Sc., F.R.S., and W. T. Haydon, F.L.S.; Hon. Treasurer, W. J. Halls; Hon. Librarian, James Johnstone, B.Sc.; Hon. Secretary, Joseph A. Clubb, M.Sc.; Council, H. C. Beasley, Margaret Cussans, B.Sc., E. Glynn, M.B., M.A., Oulton Harrison, J. Lomas, F.G.S., W. S. Laverock, M.A., B.Sc., Douglas Laurie, M.A., R. Newstead, M.Sc., A.L.S., J. H. O'Connell, L.R.C.P., Joseph Pearson, D.Sc., Prof. Sherrington, F.R.S., and E. Thompson.

4. Prof. B. Moore, M.A., D.Sc., delivered the Presidential Address on "The Reactions of Marine Organisms in relation to Light and Phosphorescence" (see "Transactions," p. 1). A vote of thanks was proposed by Mr. Beasley, seconded by Prof. Myres, and carried with acclamation.

The second meeting of the twenty-third session was held at the University, on Friday, November 13th, 1908. The President in the chair.

1. On the motion of Prof. Herdman, seconded by Mr. W. J. Halls, the following resolution was adopted:—

   "The members of the Liverpool Biological Society have received with deep sorrow the news of the recent death of Mr. Alfred Leicester. They recall that Mr. Leicester was one of the original members of the Society, has recently served on the Council, and occupied the Presidential chair during the Session 1904-05. Mr. Leicester was a valued contributor to the 'Proceedings,' and his kindly presence and helpful counsel will be greatly missed. The members of the Society desire to express their sympathy with the family of their late colleague and to send a copy of this resolution to Mrs. Leicester."

2. The following exhibits with demonstrations were made:

   (*a*) Microscopic preparations by Miss Thornely.

   (*b*) Various apparatus by Mr. Douglas Laurie.

   (*c*) Lantern photographs of living Lepidoptera, taken by Mr. Hugh Main, B.Sc., by Mr. Oulton Harrison.

3. Prof. Herdman submitted the Annual Report on the work of the Liverpool Marine Biology Committee and the Port Erin Biological Station (see "Transactions," p. 35).

4. A note on two amphipods from Menai Straits by Mr. Alfred Walker, F.L.S., was submitted (see "Transactions," p. 101).

The third meeting of the twenty-third session was held at the University, on Friday, December 11th, 1908. The President in the chair.

1. Mr. E. Thompson exhibited, with remarks, a specimen of Leaf Insect.
2. Mr. Douglas Laurie submitted a paper on "Mendelism," and gave an account of certain results obtained by him in the colour markings of mice, bearing out Mendel's law.

The fourth meeting of the twenty-third session was held at the University, on Friday, January 15th, 1909.

1. On the motion of the President, seconded by Mr. H. C. Beasley and Mr. W. T. Haydon, the following Resolution was silently adopted:—

   "That the members of the Liverpool Biological Society desire to place on record the loss the Society has sustained by the death of Mr. Joseph Lomas, and their high appreciation of the work accomplished by him in extending knowledge, especially in Biology and Geology, and of the interest he has taken in the work of the Society as President, Member of Council, and valued contributor to its 'Proceedings.' That the Honorary Secretary be instructed to send a copy of this resolution to Mrs. Lomas, together with an expression of the deep sympathy of the Society with her and her family in their bereavement."
2. Mr. J. Johnstone, B.Sc., submitted the Annual Report of the Investigations carried on during 1908 in connection with the Lancashire Sea Fisheries Committee (see "Transactions," p. 117).

3. Dr. Bassett supplemented the above Report by a description of his work on "The Salinity of the Irish Sea area."

The fifth meeting of the twenty-third session was held at the University, on Friday, February 12th, 1909. The President in the chair.

1. The following exhibits with demonstrations were made:—

   (*a*) Living Boas and Python, by Dr. J. H. O'Connell.

   (*b*) Living albino Axolotl with regenerated toes, and a specimen of the Bat-fish (*Malthe vespertilio*), by Mr. J. A. Clubb, M.Sc.

2. Dr. J. H. O'Connell gave an interesting paper on "The Occurrence of Sea Anemones at Port Erin," and several new records of varieties and species were made. A series of original lantern slides were used in illustration.

The sixth meeting of the twenty-third session was held at the University, on Friday, March 12th, 1909. The President in the chair.

1. Prof. J. Arthur Thompson, M.A., of Aberdeen University, gave a lecture on the "Biology of the Seasons," illustrated by a charming series of lantern slides. In response to special invitation a large audience assembled.

The seventh meeting of the twenty-third session was held at the University, on Friday, May 14th, 1909. The President in the chair.

1. Prof. Herdman exhibited, with remarks, a block of stone, trawled off the West Coast of Ireland, on which were a great number of species of marine organisms.
2. Mr. F. H. Gravely, M.Sc., submitted the L.M.B.C. Memoir on "Larval forms of Polychaetous Worms found at Port Erin" (see "Transactions," p. 575).

The eighth meeting of the twenty-third session was the Annual Field Meeting held at Delamere Forest, on Saturday, June 12th. Mr. Robert Newstead kindly acted at leader. At the short business meeting held after tea, on the motion of the President from the chair, Mr. R. Newstead, M.Sc., A.L.S., was unanimously elected President for the ensuing session.

LIST of MEMBERS of the LIVERPOOL BIOLOGICAL SOCIETY.

SESSION 1908-1909.

A. ORDINARY MEMBERS.

(Life Members are marked with an asterisk.)

ELECTED.	
1908	Abram, Prof. J. Hill, 74, Rodney Street, Liverpool.
1888	Beasley, Henry C., Prince Alfred Road, Wavertree.
1908	Bigland, H. D., B.A., Shrewsbury Road, Birkenhead.
1903	Booth, jun., Chas., 30, James Street, Liverpool.
1894	Boyce, Prof. Sir Rubert, University, Liverpool.
1889	Brown, Prof. J. Campbell, 8, Abercromby Square.
1886	Caton, R., M.D., F.R.C.P., 78, Rodney Street.
1886	Clubb, J. A., D.Sc., HON. SECRETARY, Free Public Museums, Liverpool.
1905	Cussans, Miss M., B.Sc., Edge Hill Training College, Liverpool.
1886	Gibson, Prof. R. J. Harvey, M.A., F.L.S., University, Liverpool.
1902	Glynn, Dr. Ernest, 67, Rodney Street.
1903	Guthrie, Dr. Thomas, 9, Canning Street, Liverpool.
1886	Halls, W. J., HON. TREASURER, 35, Lord Street.
1896	Haydon, W. T., F.L.S., VICE-PRESIDENT, 135, Bedford Street, S.
1886	Herdman, Prof. W. A., D.Sc., F.R.S., VICE-PRESIDENT, University, Liverpool.

1893 Herdman, Mrs. W. A., Croxteth Lodge, Ullet Road, Liverpool.

1897 Holt, Alfred, Crofton, Aigburth.

1902 Holt, A., jun., Crofton, Aigburth.

1903 Holt, George, 5, Fulwood Park, Liverpool.

1903 Holt, Richard D., M.P., 1, India Buildings, Liverpool.

1898 Johnstone, James, B.Sc., HON. LIBRARIAN, University, Liverpool.

1903 Jones, Sir Alfred L., African House, Water Street.

1903 Jones, Dr. Robert, 11, Nelson Street, Liverpool.

1908 Jones, John Share, F.R.C.V.S., Vet. Department, University, Liverpool.

1894 Lea, Rev. T. S., M.A., St. Michael Penkevil Rectory, Probus, S.O., Cornwall.

1896 Laverock, W. S., M.A., B.Sc., Free Museums, Liverpool.

1906 Laurie, R. Douglas, M.A., University, Liverpool.

1905 Moore, Prof. B., PRESIDENT, University, Liverpool.

1908 Myres, Prof. J. L., University, Liverpool.

1904 Newstead, R., M.Sc., A.L.S., School of Tropical Medicine, Liverpool.

1904 O'Connell, Dr. J. H., 38, Heathfield Road, Liverpool.

1904 Pallis, Miss M., Tätoi, Aigburth Drive, Liverpool

1894 Paterson, Prof., M.D., M.R.C.S., University, Liverpool.

1894 Paul, Prof. F. T., 38, Rodney Street, Liverpool.

1905 Pearson, J., D.Sc., Zoological Department, Liverpool.

1903 Petrie, Sir Charles, 7, Devonshire Road, Liverpool

1903 Rathbone, H. R., Oakwood, Aigburth.

1890 *Rathbone, Miss May, Backwood, Neston.

1897 Robinson, H. C., Malay States.
1908 Rock, W. H., 25, Lord Street, Liverpool.
1894 Scott, Andrew, A.L.S., Piel, Barrow-in-Furness.
1895 Sherrington, Prof., M.D., F.R.S., University, Liverpool.
1886 Smith, Andrew T., 5, Hargreaves Road, Sefton Park.
1903 Stapledon, W. C., 2, Marine Park, West Kirby.
1903 Thomas, Dr. Thelwall, 84, Rodney Street, Liverpool.
1905 Thompson, Edwin, 1, Croxteth Grove, Liverpool.
1889 Thornely, Miss L. R., Nunclose, Grassendale.
1903 Timmis, T. Sutton, Cleveley, Allerton, Liverpool.
1888 Toll, J. M., 49, Newsham Drive, Liverpool.
1891 Wiglesworth, J., M.D., F.R.C.P., County Asylum, Rainhill.

B. Associate Members.

1903 Tattersall, W., B.Sc., Marine Lab., Moyard, Letterfrack, Co. Galway.
1905 Harrison, Oulton, Denehurst, Victoria Park, Wavertree.
1905 Carstairs, Miss, 39, Lilley Road, Fairfield.

C. Student Members.

Adams, A., Zoological Department, University.
Arnett Dear, A., Edgeworth, Bebington.
Bishop, G. S. A., 4, Richmond Terrace, Everton.
Bramley-Moore, J., 138, Chatham Street.
Clothier, H. M., Zoological Department, University.
Greenwood, Miss F. V., Edge Hill Training College, Durning Road.
Hudson, Miss K. B., University Hall, Beech Street.

Ponsonby, Miss F., Edge Hill Training College, Durning Road.

Scott, Miss D., B.Sc., University Hall, Beech Street.

Shipperbottom, Miss L., Edge Hill Training College, Durning Road.

Summers, Miss B., Edge Hill Training College, Liverpool.

University Students' Section.

Chairman: E. E. Billington.

Hon. Secretary: A. Nicholls, (Miss) B.Sc.

Members:

The Misses Lawson, Lennon, Uttley, Wildman, Heap, Horsman, Winston, Watterson, Robinson, Whitehurst, Scott, Jackson, Lee, Latarche, Southerst, Dixon, Bland, Gleave, Scott, Blackwell, Blackledge, Prescott, Matthewman, Donald, Kaye, Steppes, Edge, Knight, Coburn, Jolley, and Walker; Messrs. Brien, Billington, Harding, Wilson, Morgan, Jones, and Williams.

D Honorary Members.

S.A.S., Albert I., Prince de Monaco, 10, Avenue du Trocadéro, Paris.

Bornet, Dr. Edouard, Quai de la Tournelle 27, Paris.

Claus, Prof. Carl, University, Vienna.

Fritsch, Prof. Anton, Museum, Prague, Bohemia.

Haeckel, Prof. Dr. E., University, Jena.

Hanitsch, R., Ph.D., Raffles Museum, Singapore.

Solms-Laubach, Prof.-Dr., Botan. Instit., Strassburg.

THE LIVERPOOL BIOLOGICAL SOCIETY.

Dr. In Account with W. J. HALLS, Hon. Treasurer. **Cr.**

1908, Oct. 1st, to Sept. 30th, 1909.	£	s.	d.	1908, Oct. 1st, to Sept. 30th, 1909.	£	s.	d.
To Tea and Attendance at Meetings	4	0	0	By Balance from last Account	5	5	9
" Honorarium to Sub-Librarian	5	5	0	" 23 Subscriptions	24	3	0
" Seven Lantern Attendances	0	17	6	" 2 Associate Members at 10/6	1	1	0
" Year Book	0	7	6	" 22 Members' Arrears	23	2	0
" Postages and Carriage of Volumes	4	4	6	" 4 Members' Entrance Fees	2	2	0
" Hon. Secretary's Expenses (postages, &c.)	3	2	0	" Students' Section	1	1	5
" Messrs. Tinling & Co., Ltd.	45	0	8	" Sale of Volumes	7	17	6
" Treasurer's Expenses	0	4	4	" Bank Interest	0	6	1
" Balance in Treasurer's hands	2	18	3	" Additional Subscription	1	1	0
	£65	19	9		£65	19	9

Audited and found correct,

Liverpool, *September 30th, 1909.*

HENRY C. BEASLEY.

TRANSACTIONS

OF THE

LIVERPOOL BIOLOGICAL SOCIETY.

INAUGURAL ADDRESS

ON

REACTIONS OF MARINE ORGANISMS IN RELATION TO LIGHT AND PHOSPHORESCENCE.

By BENJAMIN MOORE, M.A., D.Sc., Johnston Professor of Bio-Chemistry, University of Liverpool; President of the Society.

The observations recorded in this address were chiefly conducted upon organisms taken by means of a fine silk tow-net in Port Erin Bay during the spring and summer of 1908.[1] In addition certain observations are added upon the reaction to light of young larvae of the plaice (*Pleuronectes platessa*) taken from the Hatchery of the Station.

The experiments on the action of light were made in April, and the attempt in September to investigate the action of light upon the phosphorescent organisms then present in the Bay, based on the supposition that organisms which themselves emitted light might possibly show interesting variations in reaction to incident light from without, led to the accidental discovery of the diurnal periodicity in the phosphorescence of these organisms, which furnishes the subject of the second section of this address.

The two sets of experiments on the variations in relation to light, and upon the diurnal periodicity in phosphorescence, are really distinct, and will be described in two separate sections.

A.—VARIATIONS IN THE REACTIONS OF ORGANISMS (CHIEFLY NAUPLII OF BALANUS) TO DAYLIGHT AND ARTIFICIAL LIGHT

Since the very existence of all living organisms, either directly or indirectly is dependent upon the energy of light, and the transformation of this into other types of energy, it is not surprising that reactions to light are amongst the most fundamental and most widely spread throughout the whole world of organized living creatures. Such reactions must have been developed in the very beginning of the dawn of life when the first living cells commenced to synthesize organic products from the inorganic materials of their environment by the use of the store of energy from the sunlight. Later on organisms arose which were only dependent upon the light at second-hand, since they were able to consume the synthesized organic products formed by other organisms converting the light energy directly, and so were only indirectly dependent upon the light for their existence. Even for this type of organism, utilizing the light energy indirectly, reactions to light remained essential in the search for food and for other physiological functions, and also there would be an inheritance of relationships to light derived from the earlier ancestry with direct dependence upon light.

---

[1] All the tow-nettings used in Section B were taken in Port Erin Bay and were surface tow-nettings, some of those used in Section A were kindly taken for me outside the Bay by Prof. Herdman.

At a later stage structures or organs arose specially adapted for light reactions, and in those living creatures possessing such organs there probably came a deterioration of the sensitiveness to light of the remaining cells of the body. But in spite of all such decline in direct sensitiveness to light, there must have remained some trace of their old primeval relationships to light.

Experimental evidence of this persistence of relationship to light of all cells exists of two kinds; there is first the deleterious effects of complete withdrawal of light for prolonged periods, and the necessity of sunlight for healthy existence; and, secondly, there is the direct evidence of the effects of application of strong light to animal cells seen in the Finsen effects, and in other forms of radiant energy allied to light.

It is, however, in the more lowly organized types of both animal and vegetable organisms that the strongest and most direct reactions to light are observable—apart from the particular case of the reaction of chemical synthesis in the chlorophyll-containing cells of the green parts of the higher plants.

Examples of this reactivity are seen in the effects of sunlight upon nearly all types of bacteria; in the sudden outburst of vegetable life in the form of diatoms in the spring of each year as the length of the day increases and the more vertical light reaches and penetrates the water before there is much increase in the temperature of the sea— an outburst upon which the whole life of the sea is as thoroughly dependent as that of the terrestrial world is upon the similar outburst of activity in land plants; and in the most marked movements which occur towards or from the light according to varying circumstances of the minute organisms, either larval or adult, which chiefly constitute the plankton or floating life of the ocean.

It is hence clear that the observation of the reactions of living cells to light is of importance both to the student of biology, and to the student of medicine who makes practical applications of the discoveries of biology, using the term in its widest sense.

Recent discoveries have proven the value of light treatment as a practical adjunct of medicine, and the study of light effects upon the simpler organisms must sooner or later yield a key, both for the rational understanding of such effects, and their extension to further utility. In addition to these utilitarian advantages, the study is one of the most fascinating from its own intrinsic interest in the whole wide field of biology.

One of the most obvious lines of attack in investigating the reactions of living organisms to light is the study of the movements of the organisms, either as a whole in the case of freely moving organisms, or the change in relative position, or orientation, in fixed or sessile organisms.

It must, however, be clearly borne in mind that this movement is an index of other things, that the underlying problem is ultimately and essentially a chemical one, or, better expressed, one of chemical transformation of light energy.[1] The organisms move because of an action of light upon chemical constituents in the cells, that is to say, there is a change in the metabolism of the cell stimulated, giving rise to the movement of the organism. Also, according to the nature and condition of both cell and light-stimulus, which form the two inter-acting factors, the character and sense of the movement of the organism will vary.

---

[1] This view has been also put forward by Loeb, *Dynamics of Living Matter*, 1906, pp. 112 *et seq.*

Thus, we shall see that with the same condition and previous treatment of the organism, the reaction varies and becomes positive or negative with varying intensities of the light-stimulus, and, secondly, with the same constant intensity of light-stimulus, the reaction varies when the previous history and condition of the reacting organism have been artificially varied. That is to say, the light induces chemical alterations in the cell, and the nature and amount of the chemical changes vary with the two factors, the condition of the cell at the time, and the intensity of the incident light.

It has been clearly pointed out by Loeb that the orientations or tropisms of sessile organisms, and the movements of free organisms towards or away from light, are essentially the same in character, the free organism being first orientated and then, by the action of its locomotor organs, carried in either direction according to the sense of the previous orientation.

This is a fundamental observation which to a certain extent unifies the problem, but there still remain the questions of why the light induces orientation, the conditions under which orientation varies with the condition of the organism and the strength of stimulation, and also the remarkable fact that in higher organisms at any rate there is developed what might be described as *resistance* to orientation, so that the organisms accumulate either at the proximal or distal point to the light and yet lie in all possible planes of orientation, and, further, that they move about within a certain zone in all possible directions.

It is in fact self-evident, and may be taken as axiomatic, that there must have been a certain degree of orientation, or steering, or the organisms would never have been able to move either to or from the light. But this, it is to be observed, is quite different from the organism being turned round when the movement first begins, being definitely held there by the influence of the light in a fixed plane, and then as a result moving towards or away from the light.

The experiments to be recorded later show clearly that there is no such fixed or rigid orientation keeping the organisms in a constant plane, but rather a continually directed control bringing the organism back more or less towards the same direction as it darts about under other varying influences and stimuli, and this on the whole gives steering to the course, so that the animal as a net result moves towards or away from the light.

Taking this movement then as a sign of chemical change in the cells of the organism, or certain of those cells, the effects were observed—of exposure of organisms to light of varying intensities, of change in reaction as a result of keeping in light of about constant intensity, of velocity of movement in light of varying intensity, of the effect of light of different colours, and of velocity of movement in such lights, of the effects of converging and diverging light, of the effects of light and shade on organisms in the same vessel, on the association of upward or downward movements in level with positive or negative phototaxis, and on movement in presence of more than one source of light.

A very considerable literature exists dealing with heliotropism and phototaxis, but no attempt need be made to quote from this, further than relates to the organisms used for the research, or in incidental relationship to the variations in reaction to light described in the present experiments.[1]

The experiments were made with a free-swimming larval stage of the Barnacle (Nauplii of Balanus), obtained in by far the largest quantity in the tow-nettings, mixed with a much smaller number of copepods, and larval spirochaetes.

The manner in which the organisms congregate at the points of the dish nearest to and farthest from the light was used to pipette them off and separate them from other organisms indifferent to the light, and the positive and negative groups of organisms so obtained were examined separately. Many of the Nauplii were found in both the positive and negative groups, but no difference in average size or degree of development could be found in the two types to differentiate them, and later experiment showed that the same separated group might be artificially varied backward and forward between positive and negative according to their previous treatment by light.

---

[1] For a general survey and for literature, reference may be made to Verworn, *General Physiology*, translation by Lee, 1899; Holt & Lee, *American Journal of Physiology*, Vol. IV. p. 460, 1901; and Loeb, *Dynamics of Living Matter*, 1906.

The phototaxis of the Nauplius of Balanus has been examined by Loeb, and Loeb and Groom, and Loeb[1] states that they are positively heliotropic upon leaving the egg, but soon become negatively heliotropic. This I consider is entirely due to over-stimulation by the light, for on keeping for some time in darkness the negative organisms become strongly positive to the same intensity of light in which they were previously negative, and in which part of them left during the same interval have continued negative. The statement of Loeb and Groom that they remain positive in artificial light (gas flame) is confirmed by the results of my experiments, but holds up to a certain intensity of illumination only, for if the light of a small lamp was converged by means of a cylindrical museum jar in which the organisms were contained, the organisms in the strongly illuminated area gradually became negative and passed into the shaded parts or to the distal pole.

In later experiments made at Berkeley, U.S.A., Loeb found that Nauplii there behaved differently from those examined in his earlier experiments made at Naples, and showed more complicated reactions.

Working with the larvae of Polygordius, and with those of Limulus, Loeb noticed a phenomenon which was also conspicuous throughout the present series of experiments, namely, that the positively phototactic organisms gathered in a group towards the top of the vessel, while the negative organisms at the same time as they gathered away from the light congregated at the lower part of the vessel near the bottom.

This I have also invariably observed when a tow-netting is brought into the Station and placed in the diffuse light of a window in a glass jar. The positive organisms are in a compact group nearest to the window, and almost at the surface of the water; while the negative ones are at the most distal point of the jar from the window and down near, or on, the bottom. The same arrangement holds even in a shallow dish, well illuminated throughout its depth, the positive organisms are up close to the surface, and the negative ones on the bottom of the dish. The arrangement continues when the organisms are lit in the dark room by a candle on the same level as the water—still the positive ones are near the surface and the negative ones near the bottom.

[1] *Loc. cit.*

I consider that the most probable explanation of this is the constant association, in the natural habitat of the organisms (the sea), of swimming upwards towards the light when positively phototactic, and downwards towards the darker regions of water when negatively phototactic.

In addition to the interest of this association on its own account, it seems to me to be valuable as a sign that the light not only affects the sensitive area on which it acts, but also indirectly affects the whole organism, the chemical changes set up at the sensitive area communicating changes to the whole organism, which stimulate it and cause it to rise or sink in the medium.

Loeb, working with Gammarus, found that traces of acid made the organisms more strongly positive, and traces of alkali tended to produce a negative heliotropic effect. I have not been able to obtain similar results with hydrochloric acid, or caustic soda, in Nauplius, although both reagents were pushed to the limits compatible with life, viz., $\frac{1}{500}$ normal.[1] The organisms in the dishes to which either acid or alkali was added seemed to behave exactly like the untreated control. I do not, however, consider this any contradiction of Loeb's results, since the organisms used were different. Moreover, Loeb's results are such as would be expected from the knowledge that alkalies, within the compatible range, excite the activity of living matter, while acids depress it. For, if we regard the light effect as producing an increased chemical activity, then the optimum value of reaction, at which the change would occur from positive to negative as the intensity of the illumination was increased, might be expected to be reached sooner in the case of an organism already made hyperactive by alkali than in the case of an organism where the activity was depressed by added acid.

Throughout the whole series of my experiments I have consistently found that the phototaxis is positive with very feeble illumination, and becomes negative as the strength of the light is increased. Further, continued illumination, either by diffuse daylight or by a very bright artificial illumination, causes an increasing number of organisms to become negative, and keeping in darkness or in a feeble illumination causes this negativity to pass back to a positive phototaxis.

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[1] The limit of acidity or alkalinity compatible with life seems to have *nearly* the above value for all unprotected minute organisms of either vegetable or animal origin.

This again is compatible with the view that the effect of light upon the sensitive substances of the organism is always the same whether the effect is shown by a positive or negative phototaxis. The degree of the stimulus determines the reaction of the organism towards it, as shown by the direction of the orientation and consequent movement, but the chemical nature of the stimulus is the same. Below a certain optimum the organism reacts so that the sensitive surface is turned towards the light, that is to say so as to increase the amount of light energy reaching it, and so *increase* the reaction towards its optimum value for the organism in its condition at the given moment. Above the optimum value of stimulation, the organism conversely reacts so as to turn the sensitive surface into a region of diminished light intensity, and so also to *decrease* the velocity of the reaction towards its optimum for the organism.

This supports the view expressed by Holt and Lee,[1] that direction of light is only effective in a secondary manner in so far as it alters intensity of light falling upon different parts of the organism, and the orientation is hence primarily a question of intensity of light.

The very ingenious experiment of Loeb, showing that an organism which is positively phototactic to direct sunlight will pass from this onward into diffuse sunlight, that is, into a region of lower intensity of illumination, and will not reverse its direction when it finds itself in this region of lower illumination, is quite susceptible of explanation on this view, as well as the result of the experiments given below in this text, upon the movement of negatively phototactic organisms away from the source of illumination in converging light, and still onward past the focus of the light in now diverging light with decreasing intensity.

Loeb's experiment consisted in placing an organism (young caterpillars of *Porthesia chrysorrhaea*) in a test-tube the axis of which was horizontal and at right angles to the plane of a window near by, through the upper part of which direct sunlight fell on the more distal portion of the test-tube, while the portion of tube near the window was lit only by diffused daylight. Under such conditions these animals, which react positively, did not halt at the junction of diffuse light and direct sunlight and turn again backwards to the stronger light, but proceeded on in the feebler light toward the incident point right up to the end of the tube.

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[1] *Loc. cit.*

From this experiment, Loeb argues strongly against the anthropomorphic point of view which would assign any choice to the animal as to whether it sought, or turned from, the light because the light was pleasant to it or the reverse, and urges that the whole process is mechanical or automatic, the animal's head being turned by the stimulus irresistibly towards the light, and the whole movement following inevitably upon this turning.

Without assuming any extravagantly anthropomorphic point of view, it may be maintained that the ingenious experiment scarcely supports the interpretation placed upon it, and that the whole matter depends upon the force of the stimulus outweighing the degree of development, of what represents the intelligence of the animal, or, if the expression is more suitable, the development of the nervous system, or, in more general terms still, the co-ordination of the organism.

When the animal's body or the sensitive area of it passes from the area of direct sunlight into the less illuminated area of diffuse daylight, in order to turn back into the brighter area of sunlight, the sensitive surface would require for a time to be turned away from even the diffuse light into a region of shadow from its own body, that is to say, it would require for the time to behave as a negatively phototactic animal, and reduce the intensity of illumination of the sensitive area. This supposes a degree of intelligence and of memory for the 'pleasanter' (or more near the optimum) stimulus which the organism does not possess, and hence it does not turn; but a more highly organized animal would turn, and once more seek the stimulus which suited the organism best.

It is such excess of stimulus over organization which makes the moth burn itself in the flame or the bird dash itself to pieces against the lighthouse lantern, and in my opinion this differs in degree of complexity only, but not in kind, from the strength of the irresistible impulse which forces the victim of any drug habit to keep on drugging himself, or leads the unfortunate human being with an incoordinated or improperly balanced nervous system into committing crimes against himself or others. The germs of resistance to stimuli, or rather of reacting so as to alter strength of stimuli, must be present in all living creatures, or life and continuance of the species would speedily become impossible; and it appears to me that denial of this would be nearly as great an error as the view which appears to be held by some opponents of the advance of physiological science, that all organisms and animals are about equally sentient to stimulation and to pain.

The experiments conducted with organisms under different coloured glasses, described below, in which the relationship of the two halves of the dish to the direction of the incident light was identical, also show, from the selection of one-half of the dish by the organisms in preference to the other, that the organisms seek that region where the light activity possesses an optimum for them although there is nothing in the incident direction of light to lead them to swim under one particular glass as a result of orientation.

The same is seen in the experiments of Oltmann[1] and of Holt and Lee, in which a range of varying intensity of light was arranged by means of a prism placed along the long side of a long glass trough containing organisms. The incident light came in varying intensity perpendicularly through the prism, and the organisms were then found to place themselves in certain intermediate positions where the intensity of light suited their optimum, although they had to move to this position practically at right angles to the direction of incidence of the light.

Experiments were made in the present series of observations upon the velocity with which the organisms moved in light of varying intensity, and also under glasses of varying colour, and it was found that within the limits of the experiment, the velocity of movement was practically constant, thus showing that the chemical reactions set up by the light did not affect the locomotor organs.

DESCRIPTION OF EXPERIMENTS

Experiment I.—A tow-netting was taken in Port Erin Bay, April 21st, 12—1 p.m. After stirring up in sea-water, it was divided into five portions of 300 c.c. each, which were placed in white soup plates and treated as follows:—

No. 1.—Control, untreated.

No. 2.—Added 3 c.c. of $\frac{N}{10}$ HCl, making $\frac{N}{1000}$ solution.

No. 3.—Added 6 c.c. of $\frac{N}{10}$ HCl, making $\frac{N}{500}$ solution.

No. 4.—Added 3 c.c. of $\frac{N}{10}$ NaOH, making $\frac{N}{1000}$ solution.

No. 5.—Added 6 c.c. of $\frac{N}{10}$ NaOH, making $\frac{N}{500}$ solution.

The dishes were left in the diffuse daylight of a north window, and examined after two hours (3 p.m.), the arrangement of the organisms is found to be the same in all five plates, showing no change due to acid or alkali, and this persisted throughout the experiment.

In each of the dishes there are two prominent groups of organisms, a larger group at the part nearest the window and close to the surface of the water, a smaller, but well-marked group at the diametrical pole farthest from the window and at the bottom of the plate.

On shading, for a few minutes, half of one dish with a cardboard, the line of shade of edge of cardboard being at right angles to the plane of the window, in the illuminated half of the plate there is a thick group at the nearest point to the window; in the darkened semicircle, immediately on lifting the card, a smaller group is seen at the point distal to the light, and also there is a diffusely scattered but increased number over all this previously dark half, much greater than in corresponding areas of the illuminated half.

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1. Quoted by Holt & Lee, *loc cit.*

Examined again at night (8—9 p.m.) by lamp-light when nearly all the organisms in the plates come to the point nearest the light. Shading as before with shadow parallel to direction of incidence, gives a compact group in the illuminated half near the light, but a great many are in the darkened half which possesses a diffuse group at farthest point from light.

Examined again April 23rd, noon (about forty-eight hours from commencement of experiment). Took the control plate of organisms into a south room having direct strong sunlight from an open window. The organisms after a time collect *very* slightly to sun side, but in the quite open unshaded plate are fairly indifferent, being distributed all over.[1] Now one-half of the dish was shaded by cardboard, the line of shade, as on previous occasions, being arranged parallel to incidence of the light; at once all the organisms came out into the sunlit half, somewhat more at the point nearest to the sun. On reducing the sunlit part to a very small space, it became crowded with organisms accumulating more densely at the point nearest to sun. This compact group of organisms was pipetted off from the *white* plate into a *black* vulcanite half-plate photographic developing dish, containing sea-water, when the organisms, *at once almost*, accumulate at the part of the dish *farthest* from the sun. The half of the black dish farthest from the sun, after stirring up, was covered over (that is, with the line of shade at right angles to plane of incidence), and the organisms all collect, at remotest end of shaded part, away from sun.

This peculiar reversal in the black dish is difficult to explain, unless it was due to the absence of reflection. The result could not be repeated in other experiments because the organisms were never again found indifferent in sunlight, but always strongly negative, even in the white plates.

The organisms in this experiment were observed for four days longer; at the end of the third day they had become very strongly negative in the diffuse daylight of the north window, a reversion, it will be observed, from their original mixed condition with a large preponderance of positive organisms. While in this strongly negative condition they were taken into the dark room and tested with lamplight from a small oil lamp. At once there was a change; three of the five, viz., Nos. 3, 4, and 5, were now altered to positive, while Nos. 1 and 2 were mixed, partially positive and partially negative.

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[1] This is a very exceptional behaviour in sunlight.

The plates were left in the dark room over-night, the only trace of illumination being a very faint ruby light, coming from a small borrowed light through the double thickness of a ruby window and ruby photographic screen.

The following morning, as soon as a light was struck in the dark-room, it was seen that all the organisms in all the plates were collected at the points nearest to the faint ruby light.

The small oil lamp was lit and the plates arranged round it; all five showed the organisms strongly *positive*. Taken out immediately from the lamplight to the diffuse daylight of the north window again, the organisms in all five are found to be strongly negative. No interval save the time of shifting the plates out from dark room to window bench elapsed between these two observations with reversed results.

Experiment II.—Tow-netting taken by Professor Herdman, on April 23rd outside the Bay. On standing in diffuse daylight of north window, two large groups separate in the glass jar; as usual, one towards light and at top, the other away from light and at bottom of jar. These two groups were separated off by pipetting into two soup plates, one containing the positive group, the other the negative group, and both were found to consist chiefly of Nauplii of Balanus.

The negative group was taken first for examination in the dark room. On lighting one candle the organisms swim to the opposite pole; on placing two candles at opposite diameters of the plate, the organisms lie in the middle, half-way between the two lights; with four candles placed around equi-distant, the organisms are clustered compactly at the centre of the plate. The positive organisms similarly examined show a grouping around the periphery of the plate accentuated opposite each candle.

The organisms were left in the dark room overnight and examined in it next morning. On first striking a light, *both* sets of organisms were seen clustered at nearest point of each plate to the exceedingly faint ruby light. One candle was lit and placed close to the plate containing the previously *negative* organisms, these are now nearly all *positive* to this intensity of light. Next morning (11 a.m.) both sets of organisms, which had remained in the dark room overnight, when tested by candle light were strongly positive. They were at once taken out of the dark-room and placed on the window bench in the north room in fairly strong diffuse daylight (it had been snowing, and the hill across the Bay from the Station was covered with snow). All the organisms in the originally negative plate were now negative again: those in the originally positive plate were mixed about three-fourths negative and the remainder positive.

The two plates were once more carried back to the dark room and tested to candle light. The originally negative plate, which a few minutes before had been completely positive in the dark room to candle light, had now, on account of its short sojourn in the diffuse daylight, turned to partially negative and partially positive in about equal groups. The originally positive group was still all positive to the candle light, although a few minutes previously in the diffuse light of the window about three-fourths of the organisms had been positive.

Three points are shown clearly in this experiment.

First, that the reaction varies *in the same organism at the same time* with the intensity of the light, and that feeble illumination gives a positive reaction and strong illumination a negative one.

Secondly, with the same intensity of illumination the reaction varies with the previous history and exposure to light of the organism. Exposure to darkness or feeble illumination turns the organism so that it reacts positively, and previous bright illumination changes it so that it reacts negatively to a strength of stimulus to which it before acted positively.

Thirdly, throughout these series of changes the original bias of the particular set of organisms persists, the other effects being superposed in a roughly algebraic summation. Thus the original trends towards positive and negative in the two sets of organisms dawn out again at the end of the experiment.

Experiment III.—On velocity of movement in light of varying intensity and colour.

This experiment on the velocity of movement in light of different intensity and of different colour, was made by observing the time required for the organisms to swim from one end to the other of a flat, black vulcanite dish of rectangular shape. The length of the dish was 17 cm., and the organisms were first brought to a compact mass at one side by placing the light to be used at one end and then the time noted for them to swim across and form a similar compact mass at the other end when the source of light was shifted to that end.

Then the time was again noted which they require to swim back to their original position; these times are denoted by 'Out' and 'Back' in the following table. In taking the time 'out' one does not wait for every organism, but waits till the great majority are in a compact group, this, after a little practice can be done accurately within a quarter of a minute or less.

For different intensities of light, one ordinary paraffin wax candle was used in one case, and four similar candles in the other case. For white light, the dish was simply uncovered, and for coloured lights it was covered completely over with slips of coloured glass, through which the coloured light passed to reach the organisms. The coloured glasses which it was possible to obtain were red, green and blue. Regarding the total intensity of light passing through the three slips, it appeared to the eye as if the red strip was most obscure, and the green most transparent, the blue being intermediate, but no exact photometric instrument was available. The organisms used were a strongly positive group obtained by pipetting off in diffuse daylight.

1. Illumination intensity = one candle.
    Red light ... Time 'Out' ... 3 min. 0 secs.
    Time 'Back' ... 3 min. 0 secs.
    Blue light ... Time 'Out' ... 3 min. 30 secs.
    Time 'Back' ... 3 min. 20 secs.
    Green light ... Time 'Out' ... 3 min. 40 secs.
    Time 'Back' ... 3 min. 0 secs.
2. Illumination intensity = 4 candles.
    White light ... Time 'Out' ... 3 min. 0 secs.
    Time 'Back' ... 2 min. 50 secs.
    Red light ... Time 'Out' ... 3 min. 0 secs.
    Time 'Back' ... 3 min. 0 secs.

Experiment IV.—Selection of position under different coloured glasses with the same direction of incidence.

In this experiment, diffuse daylight was used on some occasions and candlelight on others, the long side of the dish being placed parallel to the surface of the window, or next to the candles. Then the two glasses of the two different colours to be compared were placed edge to edge, each covering one-half of the dish, the edge where the two slips of glass touched being at right angles to plane of window, so that each half was situated exactly the same as to direction of incidence and intensity of light from the window; and a similar arrangement was used with the candlelight, the candles being so placed opposite the middle of one of the long sides of the dish that they shed equal light on the two different coloured halves. Before placing the two slips over the dish, the contents were stirred so as to uniformly distribute the organisms, but care was taken that the contents were not rotating when the slips were put over. Also, after the organisms had distributed themselves selectively, and the result had been noted, the two slips were reversed in position, each to each, and the change in distribution observed: the organisms at the time were strongly positive in the candle-light, and strongly negative in the diffuse daylight.

First, using four candles in the dark room, and with the red glass on the left-hand half and the blue glass on the right-hand half, in 2 min. 30 secs. from the commencement all the organisms are under the blue glass and next the candles, none under the red glass. The red and blue glasses are now reversed without disturbing candles or organisms, and in a very short time all the organisms have shifted and are once more under the blue glass in its new situation.

Second, similar results obtained with diffuse daylight, except that organisms now swim from the light; with blue and red most of the organisms under blue, a few only under red; with blue and green, two groups form at the two corners distal to the light, the larger of the two groups being under the green. Thus the organisms move with equal velocity under all coloured glasses, but when two colours are offered for selection they accumulate chiefly under one. Further, the direction of movement to pass from one colour to another is across the direction of incidence, and not to or from the light, and the relation to the light of the two halves being the same, it would appear that a preference for a particular colour or wavelength (or the greater or lesser stimulus of different wavelengths), caused the different distribution. If the organisms are carefully watched when they are becoming distributed, it is seen that they do not move directly across from one half to the other, but are moving about apparently freely, an organism every now and then leaving a group and darting off; but there is a certain amount of steering and controlling during these apparently free movements, which ultimately settles them down in their final distribution.

In this type of experiment, observation of the grouped animals shows, as in all the other experiments where the animals are grouped either positively or negatively under the influence of the light, that there is no such thing as fixed and continuous orientation of the minute animals. In every group a great many are moving about in and out amongst one another, and a good many are entering and leaving the group like bees from a hive, but each individual, after a short trip about soon returns to the group. The source of light is, in fact, a strong directive influence, but there is no rigidly fixed orientation, any more than there is in a cluster of midges, or a brood of chickens around their mother.

Experiment V.—Movement in converging and in diverging light.

In order to obtain converging and diverging light, cylindrical museum jars, about 10·5 centimetres in diameter and 18 centimetres high, were used, which happened to be in stock at the Station.

Two such jars were used; the first, filled with clear fresh water, was used only as a cylindrical water lens, and contained none of the organisms; the second jar contained the organisms in sea-water. The first cylinder was placed a variable short distance, up to about one foot, from a small oil lamp with a circular wick, and the second cylinder was placed close up against it, on the other side from the lamp. The lamp and two cylinders were so arranged that the diverging light from the lamp became slightly convergent in passing through the first cylinder, and being still further converged by the second cylinder, it formed a caustic about two-thirds to three-fourths of the way through the second cylinder, and from that onward to the concave surface of the second cylinder the light was diverging.

By this arrangement any organism moving along the path of the rays, either towards or away from the light, is forced in one part of its path to travel in converging light, and the remaining part it travels in diverging light. Experiments were carried out both with white light and with coloured lights. The first set of organisms examined were negative; these swam away from the light into light of *increasing* intensity towards the caustic, and then through this onward in light of decreasing intensity till they reached the glass surface most remote from the light. Positive organisms were next tried, and swam in the exactly reverse direction, first from the most distal part towards the caustic in converging light, and therefore of increasing intensity, and then onward in diverging light, therefore of decreasing intensity, up to the glass surface nearest to the light.

At first sight it looks proven from this that intensity of light is of no effect, and the direction of incidence the whole matter, because the organisms appear to swim in one direction indifferently, whether the illumination is increasing or decreasing. In reality, however, such a conclusion would be fallacious, for in order that, say, a *positive* organism should turn when it began to swim in light of gradually *decreasing* intensity, it would be necessary for it to turn its sentient surface away from the light, and that would plunge it into darkness.

The true conclusion is shown by what might be termed secondary effects seen on carefully watching the above experiment with negative organisms. These organisms at first accumulate in the narrow band of light at the distal glass surface from the light, where they dart about in small curves, keeping close to the glass; but in a few minutes it is found that a great many of them have accumulated in the two shady margins just outside this strongly illuminated band, and on either side of it. The probable explanation of this is that for these negative organisms the feebler light outside the band is nearer the optimal stimulus, and when they escape from the direct light beam in the course of their peregrinations, they find a suitable stimulus in the feebler light. But when any accident, such as a chance movement stimulated by some other cause, sends them again into the beam, they are stimulated to turn away from the light, and must again return *via* the distal glass surface to the refuge of the shade again.

This effect is seen still more strikingly when the red glass strip is interposed on the path of the incident light: then scarcely a single organism is seen on the illuminated strip, but two packed masses are seen on each side of it in the shade, and gradually tailing off as the distance from the illuminated strip increases. Similar results are seen with negative organisms if a narrow opaque white strip, such as a strip of cardboard, be lowered into the jar and held in a vertical position at the caustic. When the light is now placed in position, any organisms in the course of the beam, or swimming into it from the two dark zones at either side of it, turn at once away from the light, and swim along the path of the rays towards the caustic and the card: but they do not accumulate to any appreciable extent at the card, they swim round its edges and accumulate in the narrow feebly-lit space behind it.

Experiment VI.—With young larvae of the plaice (Pleuronectes platessa).

A number of young plaice larvae, which were five to seven days old, were taken from the Fish Hatchery attached to the Station, and placed in sea-water in a flat, oblong pie-dish. It was found that they were faintly negatively phototactic in diffuse daylight. Contrary to the case of the Nauplii, this appeared to be increased in lamplight as well as in direct sunlight. When the dish is brought into lamplight in the dark room, it is found that most of the larvae after some time are accumulated in the half of the dish farthest from the lamp, decreasing to a clear space directly under the lamp. There is, however, no such tight packing up as in the case of the Nauplii.

The interesting point, however, is that there is no evidence whatever of orientation in regard to the light: the larvae lie at rest with their long axes at all possible angles with the line from the lamplight, some directly facing it, some straight away from it, others nearly at right angles, and many indiscriminately at all angles. The arrangement is not a chance one, as it looks at first sight, for no matter how often the larvae are disturbed and stirred up, they finally settle with the great majority in the distal half, and lying there at rest at all angles to the direction of incidence. On shading one-half of the dish with cardboard, the line of shade being parallel to the plane of incidence, the great majority of the larvae are found in the shaded half, more in the distal quadrant, and in all lines of orientation. If cards are arranged so that one quadrant of the dish only is illuminated, that quadrant becomes almost free.

Experiment VII. Indifference of phosphorescent organisms to movement in light from without.

It was thought that organisms which themselves emitted light might show interesting results in their reactions to light from without, and this led to the work of Section B about to be described; but it was found that the phosphorescent organisms present, probably certain copepoda, were entirely indifferent to incident light, at any rate as far as movement was concerned.

Since the organisms could not be made to phosphoresce in the dark room during the day, the procedure was adopted of taking a tow-netting during the day, when the Bay was known, by observations made during the previous night, to contain abundance of phosphorescent organisms. This tow-netting was placed in diffuse daylight, and nearly all the positive organisms were pipetted off into one dish containing sea-water, nearly all the negative organisms were similarly pipetted into a separate dish, and finally, a good number of indifferent organisms were pipetted off into a third dish, from the middle of the bottom of the stock jar.

The three sets of organisms were then examined for phosphorescence after dark, when phosphorescence where organisms were present had spontaneously set in and could be further intensified by stirring. It was then found that the positive and negative portions each contained only one or two phosphorescent organisms taken up unavoidably with the others; but the indifferent set contained a large number of phosphorescent organisms. The indifferent set containing the majority of the phosphorescent organisms were also practically indifferent to candle-light. In regard to numbers of organisms in each set, the positive set were by far the most numerous, and the numbers in the indifferent and negative sets were about equal.

The experiment was varied in a fresh tow-netting by placing several flat pie-dishes containing the organisms (not separated off on this occasion as to phototaxis) around the lamp in the photographic room, just after nightfall, until the usual phototactic groups had separated, then extinguishing the lamp, and watching the spontaneous appearance of phosphorescence without disturbing the dishes. There is no spontaneous phosphorescence for a period of about two minutes under such circumstances, then it commences, and it is seen that the phosphorescent organisms are scattered about indiscriminately in each dish, and not arranged in any relationship to where the light had previously been. Sometimes the phosphorescing organisms are moving about rapidly while illuminated, but in the majority of cases they are almost or quite at rest, and it is probable that if there had been any previous movement of a phototactic character while the lamp was lit, the arrangement would not have quite disappeared in the short interval after the light was extinguished before the spontaneous phosphorescence reappeared.

The only conclusion from the experiments appears to me to be that these particular phosphorescent organisms are almost or quite indifferent to incident light.

B.—DIURNAL PERIODICITY IN PHOSPHORESCENCE

The suggestion of the work described in this section arose incidentally, as above-mentioned, and at the time the experiments were made it was unknown to me that a diurnal periodicity in phosphorescence had previously been observed and described.

A search through the earlier literature, however, revealed a description of its occurrence in Pyrophora by Aubert and R. Dubois,[1] and in Noctiluca by Massart.[2] Henneguy[3] states that Noctiluca does not

[1] *Compt. rend. acad.*, T. XLIX, p. 477, 1884; *Compt. rend. soc. d. biol.*, p. 661, 1884. See also papers in both these Journals by R. Dubois, 1884-6.

[2] *Bulletin scientifique de la France et de la Belgique*, T. XXV, p. 72, 1893.

[3] *Compt. rend. soc. d. biol.*, XL, p. 707, 1884.

light up until it has been kept in the dark for half an hour, and that the intensity is not at the maximum for another additional half-hour.

The following passage from Massart describes the variations as observed in Noctiluca :—

'The experiments show that the irritability is dependent on the alternations of day and night, the Noctiluca is hardly excitable on shaking during the day and shines only during the night. Fact still more curious, whether the organisms are submitted to the alternations of day and night, or whether they are maintained in constant illumination or constant obscurity, they still remain much more excitable during the night than during the day. It is a veritable phenomenon of memory, everything looks as if the Noctilucae preserved the recollection of the regular succession of the days and nights.'

Massart compares this to the change in position of the leaves of plants during day and night in the Oxalis and certain Papilionaceae, but adds that while the phenomenon lasts only some days in plants, in the Noctilucae it lasts until the death of the animal.

His experiments at the outside limit, however, lasted for one week only, when the organisms died; in the present set of observations the diurnal alternation of activity was followed with organisms kept in continuous darkness for twelve days, and although the number of living organisms was decreasing all the period, a few were still left alive and phosphorescent at night at the end of the period.

Since the fact of this diurnal periodicity is one of the most striking of those alternating habits or functions of the lower invertebrates which bear such a curious resemblance to memory in higher vertebrates, and, indeed, have been regarded as a rudimentary memory,[1] it may be regarded as sufficiently interesting to merit a detailed description. It appears to stand in some danger of being forgotten, since it is not mentioned even in the larger of the modern text-books, and to the best of my knowledge it has not been shown to exist in the phosphorescent copepoda, nor demonstrated as persisting for such a long period as in the present experiments. Also its onset at the close of the day and gradual extinction at dawn have not previously been followed with any exactitude.

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[1] See F. Darwin, Presidential Address, Brit. Association, Dublin, 1908.

DIARY OF EXPERIMENTS

Monday, September 21st, 1908 (8-30 p.m.). Calm night, and sea very phosphorescent. Collected plant (*Polysiphonia nigrescens*) from the rope of an old mooring buoy. The plant is covered over with phosphorescent organisms which flash most brilliantly. The specimen is preserved in sea-water and examined ashore. It shows most brilliant phosphorescence when rubbed. When a piece is put in fresh tap water in the dark it lights up most brilliantly all over for about three minutes, then gradually the light fades out, and cannot now be evoked by any process of shaking or rubbing.

Tuesday, September 22nd.—The plant was taken into the dark room at 11 a.m. and examined: no phosphorescence could now be evoked by any process, either shaking in air, stirring up in the sea-water, rubbing, or applying fresh water.

A tow-netting had just been taken in the Bay (12 noon). This was taken into the dark room at once, but no trace of phosphorescence could be obtained from it, even with most vigorous stirring.

In the evening, from 9 to 9-30 p.m., a tow-netting was taken in the Bay, the sea being very phosphorescent wherever touched by the oars. The haul, when taken into the boat, scintillated most brilliantly while being washed into sea-water in a jar. The contents of the jar, taken into the dark room at the Station, are showing spontaneous phosphorescence, and give a vivid show when stirred. Left in the dark room over-night.

Wednesday, September 23rd.—Examined the previous night's tow-netting at 11 a.m.: there is not a trace of phosphorescence to be elicited, even on stirring briskly. Examined at intervals all day in the dark room. There is not a trace of phosphorescence seen till about 6-30 p.m., when sparking first starts on stirring, just as it is growing dusk outside, and at 7 p.m. there is spontaneous phosphorescence.

Took also during the day three tow-nettings from a row-boat, each of 15 minutes' duration, at 12-45 to 1 p.m., 3-45 to 4 p.m., and 5-15 to 5-30 p.m. As each tow-netting was finished, it was taken to the Station, at once emptied into a flat pie-dish, and taken to the dark room to be examined for phosphorescence. On each such occasion the tow-nettings previously there were also examined, as also at other intervals during the day. In none of the three was any phosphorescence seen till about 5-40 p.m., when a single organism was seen to spark in the second tow-netting (taken 3-45 to 4 p.m.), but nothing in the first or third.

Examined at 6-45, when it is dusk outside, all three are phosphorescing spontaneously, bright sparks showing up, sometimes three or four at once in each dish. On stirring there is a bright display lighting up each dish. All three left over-night in dark room.

Thursday, September 24th.—Examined at 10 a.m., none of the three tow-nettings show any phosphorescence in the dark room. Nos. 1 and 3 were kept in the dark room all day, while No. 2 was kept in the daylight, but taken at intervals to the dark room for examination. No phosphorescence seen in any of the three at any time during the day; but at night (7 p.m.) all three are sparking spontaneously, showing bright sparks at intervals. The phosphorescence is increased on stirring, so that six to ten phosphorescent spots are visible at once, but the display is not so brilliant as on the previous night, probably owing to deaths.

All three left in dark room till Friday morning; the faint ruby light from the dark room window is completely shut off by banking it up with cardboard on the outside.

This same day, being a bright day with good sunlight, three additional tow-nettings were taken, at 11 to 11-15 a.m., 12-45 to 1 p.m., and 4-45 to 5 p.m., and examined in future along with the other three, being kept in dark room also. Examined as follows in dark room:—

No. 1 observed at 11-30 a.m.	No phosphorescence.
Nos. 1 and 2 observed at 1-15 p.m.	No phosphorescence.
Nos. 1, 2 and 3 observed at 5-10 p.m. ...	No. 1, Nil; No. 2, single spark on vigorous stirring; No. 3, Nil.
Nos. 1, 2 and 3 observed at 5-35 p.m. ... (Good light outside).	Nil; single spark; Nil.

Nos. 1, 2 and 3 observed at 6-35 p.m. (Almost dark outside). ...	Spontaneous sparking in all three, No. 3 most brilliant. Dish lit up in each case on stirring.
Nos. 1 2 and 3 observed at 6-50 p.m. (Quite dark outside). ..	All spontaneously phosphorescing most brilliantly.

Also at 1 p.m. to-day, a further supply of *Polysiphonia nigrescens* was collected from the old mooring rope, and examined in the dark room. It showed no phosphorescence during the day. On placing in distilled water it gives a feeble sparkling, but incomparably less brilliant than on similar treatment at night. After dark, from 6-30 p.m. onwards, the same sample sparkles when stirred, and a piece put in distilled water lights up brilliantly all over for from three to five minutes; then the light dies away, and cannot further be evoked in that piece by any of the procedures mentioned.

All six of the tow-nettings of yesterday and to-day examined again at 7-15 p.m.; all spontaneously phosphorescing, and showing up brilliantly on stirring. Same result when again examined at 8-40 p.m.

Friday, September 25th. Arrived at Biological Station at 4-50 a.m; there is just a trace of dawn in the dull, grey sky. Organisms examined at once in the dark room, where they have all still been kept over-night; all six dishes are flashing spontaneously.

On standing quietly by and watching the phosphorescence, the minute organisms are not moving about rapidly in most cases, and one can observe that each active organism is emitting a series of flashes at about the rate of one per minute, and between the flashes there is a dimmer light showing which regularly becomes increased by a flash. The effect on the eye is very similar to that of a revolving light seen at sea at some distance off. There is an almost constant dim light lit up by repeated and fairly regular flashes.

Many of the more active organisms are so still that one is able to observe clusters of four or five in nearly constant positions for some minutes, so as to give an impression of constancy of shape to the group for the time resembling a stellar constellation.

The effect in the complete darkness of the dark room is very beautiful as the undisturbed organisms spontaneously flash out in the darkness.

The organisms were now observed at frequent intervals of about ten minutes, in order to accurately note the decline and disappearance of the phosphorescence. It was observed that the number of organisms flashing out was decreasing all the time. The rate of decrease became very rapid about 5-30 a.m., when the daylight was just beginning to grow rapidly brighter outside. At 6 a.m. there was only an occasional odd flash in each dish, showing that only a few organisms in each were still active. At 6-15 a.m. only one dish (the third of those collected on Thursday) was still showing an occasional gleam: all the other five dishes had stopped spontaneous phosphorescence. At 6-30 a.m. all spontaneous phosphorescence had disappeared, but a faint display could still be elicited in all six dishes by vigorous stirring. At 7 a.m. no sparking obtainable in any dish, even on most vigorous stirring; same result repeated at 7-30 a.m.

The organisms on the *Polysiphonia nigrescens* behave similarly to the free organisms in the dishes throughout. It was feared that the organisms would perish if the sea-water were not changed, so Nos. 1 and 2 of the Wednesday tow-nettings were filtered in the dark room through the silk of the tow-netting, and then the net being turned (so that no fresh organisms could be introduced), the organisms were washed into a fresh quantity of sea-water poured on to the net. Hence there were in future five dishes to observe instead of six, but no alteration in rate of survival on account of the changing was observed, and, as the other dishes of organisms appeared to be doing well, the process of washing into a fresh supply of sea-water, which was exceedingly difficult and awkward in the quite dark room, was abandoned.

The organisms were next examined at 1 p.m., when vigorous stirring failed to call forth a single spark in any of the tow-nettings or on the weed.

The next examination was at 9 p.m., when every one of the dishes showed spontaneous phosphorescence. The display in the three Thursday nettings is not so vivid as on the previous night, there being fewer organisms phosphorescing. It is also noticeable that the phosphorescence is not so vigorous in each individual organism. The flare out is perhaps as great, but the light completely dies out in all cases after each flare, and the period between the flares seems to be lengthened, so that one cannot pick out a particular organism by its flashes and keep track of it. The two dishes from the Wednesday tow-nettings, which are to-night showing for the third time, are not much decreased in vigour from the second night, either in frequency of spontaneous flashing or in vividness on stirring them. Nearly as many phosphorescing organisms appear to be present, and the flashes are about as bright as on the preceding night.[1]

These Wednesday organisms have now lit up for the third time, having been quite quiescent in the intermediate periods of daylight in the outer world. One of the two dishes has been in complete darkness throughout the period. From this onward all the sets of organisms are kept in complete darkness the whole time.

Saturday, September 26th.—The organisms were examined at 11 a.m., and again at 1 p.m., when no sparking was occurring, nor could any be evoked by vigorous stirring. The next observation was commenced at 6-07 p.m., when the daylight was commencing to fade outside. The dishes were not stirred, but quietly watched in the complete darkness. When the first spontaneous flash occurred, the dark room was quitted and the time noted; it was 6-13 p.m. Between 6-15 and 6-30, six flashes were counted; between 6-30 and 6-45, twenty-two flashes; between 6-55 and 7-15 p.m., there were twenty flashes. The display is much less marked than on the previous evenings. On stirring the dishes, three or four organisms can be made to phosphoresce at once in each case.

The organisms on the *Polysiphonia nigrescens* are also phosphorescent on stirring.

Sunday, September 27th.—Examined at 10-30 a.m.; no phosphorescence, either spontaneous or on stirring, from any of the dishes.

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[1] This was observed in nearly all the experiments, a great drop during the first twenty-four hours, and then a very slow death-rate in the residue.

Re-examined at 7 p.m., four of the dishes show spontaneous phosphorescence, the rate of sparking being extremely slow. The remaining dish (the third of the Thursday tow-nettings) has undergone putrefaction, and shows no phosphorescence, even on stirring. It is taken from the dark room, and all the organisms in it are seen to be dead.

Stirring elicits two to four phosphorescent organisms at the same time in the remaining four dishes.

Monday, September 28th. Examined the four dishes at 2-30 p.m.; no phosphorescence obtainable from any of them. Examined again at 7-30 p.m. Two spontaneous sparks seen in the Wednesday dishes in an interval of about five minutes; no spontaneous phosphorescence seen in the Thursday dishes. On stirring, about six phosphorescent organisms seen in one of the Wednesday dishes, and three or four in the other; one seen in the first of the Thursday dishes, and three or four in the second.

Tuesday, September 29th.—Examined at 3-30 p.m.; no phosphorescence visible or obtainable. Examined again at 9 p.m., there is spontaneous phosphorescence in both of the Wednesday dishes, and in one there is an organism which remains steadily phosphorescent with a dull glow all the time. On stirring, about six phosphorescent organisms are visible in each of the Wednesday dishes, and the sparking is brilliant. In the Thursday dishes, on stirring, there is less display, only two or three organisms showing up at once in either. The few organisms are, however, quite active, and a single organism in each case lights up so as to illuminate the contents and sides of the whole dish.

Wednesday, September 30th. Examined at 11 a.m.; no phosphorescence, spontaneous or otherwise. Examined again at 7-30 p.m., no spontaneous phosphorescence during a period of about 5 minutes, but on stirring there is a good display in all four dishes. This is the eighth night of appearance of phosphorescence in the Wednesday lots, and seventh night for the Thursday organisms.

Thursday, October 1st.—Examined the four dishes at 11 a.m.; no phosphorescence, spontaneous or on stirring. Examined again at 7 p.m., there is spontaneous phosphorescence at a slow rate in three (two Wednesday and one Thursday), and in all four on stirring.

Friday, October 2nd.—Examined at 3 p.m.; no phosphorescence, either spontaneous or on stirring. Examined again at 9 p.m.; in one of the Wednesday dishes there is an organism which remains permanently lit up the whole time of observation, about seven minutes. Spontaneous phosphorescence seen in the other Wednesday dish, and in one of the Thursday dishes. All four give phosphorescence on stirring.

This is the second time a continuously phosphorescent organism has been observed. It may be a pathological condition of the organism.

Saturday, October 3rd. Examined at 4 p.m., no phosphorescence of any kind; did not examine after nightfall this day.

Sunday, October 4th.—Examined at 12 noon, no phosphorescence in any dish, either spontaneously or after vigorous stirring. Examined again at 6-20 p.m., and watched at intervals till 8-30 p.m., but there is no spontaneous flashing. On stirring, however, there is phosphorescence obtainable in each of the four dishes, one or two organisms only flashing in each case.

The experiments were brought to an end at this date. When the dishes are taken to the light it is found that only a small number of organisms are visible and alive in each, and there is much débris of dead organisms.

The diurnal periodicity of the phosphorescence had been observed for twelve days and nights in the case of the organisms collected on Wednesday, September 23rd, and for eleven periods in the case of those collected on Thursday, September 24th, without any exception. During this interval, with the exception of one of the Wednesday dishes which had been exposed to light on the first Thursday of the period, all the dishes were kept in continuous darkness, yet at the close of the day the organisms always lit up, and lights were extinguished about daylight in the morning.

The four dishes of organisms were now filtered one after the other into the small end of the same tow-net, washed out into a little sea-water, and fixed with five per cent. formol.

The fixation was carried out in the dark room in order to observe if there was any phosphorescence. About six bright points shone out, two of which persisted brilliantly for about three minutes, and then faded out.

The weed (*Polysiphonia nigrescens*) was kept in the dark from the Thursday (September 24th) till Wednesday (September 30th), showing phosphorescence at night and none during the day. Fearing that it would decompose, it was then placed in ordinary diffuse daylight in a vessel with running sea-water. This treatment increased the amount of phosphorescence enormously, and in a day or two it was quite as phosphorescent as at first. Taken from the diffuse daylight to the dark room for examination, it was never phosphorescent, but at night it always phosphoresced most brilliantly. It, also, at the end, was fixed in 5 per cent. formol, and in this process lit up about twenty seconds after the application of the formol, and shone vividly for about three minutes before dying out.

The examination of the united tow-nettings was difficult on account of the majority of the organisms being dead and in a broken-up condition through the long duration of the experiment, but the following account was kindly given me by Mr. A. Scott, to whom my best thanks are due:—

DIATOMS.—*Biddulphia mobiliensis*, 1,000; *Chaetoceros densum*, 50; *Coscinodiscus radiatus*, 50; *Trochisca sp.*, 250.

COPEPODS.—*Calanus helgolandicus*, 20; *Pseudocalanus elongatus*, 680; *Temora longicornis*, 100; *Centropages hamatus*, 10; *Paracalanus parvus*, 100; *Isias clavipes*, 100; *Copepod nauplii*, 100; *Copepod Juv.*, 200.

MOLLUSCA (larval).—Gasteropods, 150; Lamellibranchs, 500.

No Noctilucae were present.

It is not probable that the diatoms or molluscan larvae were phosphorescent, so that there is little doubt that the phosphorescence was due to the copepods present, or certain species of these.

The following is a statement of the contents of the routine tow-nettings always taken of the plankton of the Bay, for the statistical work of the Biological Station, on the date (Thursday, September 24th) when the second set of tow-nettings were collected for the observations:

DIATOMS.- *Biddulphia mobiliensis*, 800; *Chaetoceros decipiens*, 600; *Ch. densum*, 440; *Coscinodiscus radiatus*, 50; *Streptotheca thamensis*, 150; *Trochisca sp.*, 50.

DINOFLAGELLATA, &c.—*Ceratium furca*, 50; *C. fusus*, 100; *C. tripos*, 100; *Tintinnopsis sp.*, 600.

COPEPODA. *Calanus helgolandicus*, 50; *Pseudocalanus elongatus*, 3,180; *Temora longicornis*, 280; *Centropages hamatus*, 65; *Acartia clausi*, 2,200; *Oithona similis*, 1,750; *Paracalanus parvus*, 830; *Isias clavipes*, 160; *Copepod nauplii*, 3,960; *Copepod juv.*, 2,180.

MOLLUSCA, &c. Lamellibranch larvae, 280; Oikopleura, 3,800.

Whether this diurnal periodicity has the same physical basis in a rudimentary fashion as memory in higher animals, is still an open question, for it is open to believe that the alternating play of light and darkness upon those cells which produce the phosphorescence may have induced in them a periodicity of activity and rest which still persists after the alternating stimulus is withdrawn. The process may, for example, be due to a secretion by certain cells which phosphoresces as each drop is produced, and this process of secretion may have a period of rest during the day and activity during the night. The rhythm of this activity may be timed daily under ordinary conditions, and regulated by alternation of light and darkness. During the day there would be storage in the cell, and at night discharge. On the removal of the stimulus of light during the day this state of alternation of rest and action might persist for a long period.

CONCLUSIONS

1. The characters of the response of an organism by movement to light are not constant for a given organism, but vary for the same organism at the same time according to the intensity of the light and the previous history of the organism in regard to light. As a general rule, the organism is positive to feeble light and negative to stronger light, and for a constant intensity of light at a given moment previous darkness or weak stimulation tends to turn organisms positive, and previous exposure to bright light turns them negative.

2. Both the positive and negative behaviour to light may be explained on the basis of one chemical action of light upon the cell (a katabolic one). The positive state indicates that the speed of reactions in the cell lies below a certain value, which may be called the optimal value, and the negative state corresponds to a speed of reactions in the cell above the optimal value. In the former case the sentient surfaces are turned into the light to increase velocity of reaction up towards the optimal value; in the latter case the sentient surfaces are turned away from the light so as to decrease the velocity of the reactions down towards the optimal value.

3. As a result of the orientation so caused, there arises movement of the organism towards or away from the source of light, but such orientation is not a fixed orientation, but rather a steering action; the animals as a result do not remain in one fixed plane or direction of movement, but the net result of the movement is that the organisms move to or from the light. When the movement is finished the organisms (plaice) may lie in all possible planes of orientation to the light.

4. Movement towards or away from the light has in some organisms (Nauplii of Balanus) an associated movement upwards or downwards. These two movements would coincide together in natural movements of the organisms under the influence of light alone in the sea.

5. In the case of Nauplii of Balanus, addition of small amounts of acid or alkali was not found to alter the reactions to light.

6. The rate of movement of the organism (Nauplii) is almost the

same with different intensities of light and different coloured lights, showing that the locomotor apparatus is not affected by the light, but continues to work at the same rate.

7. The particular organism used (Nauplius of Balanus) moves from red light to blue light, and from blue to green, under such circumstances that the incident light is the same in direction for both coloured regions. This would indicate that with the particular total intensities being used for the experiments, green is a more suitable or optimal stimulus than blue, and blue in turn more optimal than red.

8. Movement in converging and diverging light is described and shown to be explicable on the basis of intensity of light alone, and that direction produces its effects in a secondary manner on account of the light and shade effects of the animal's own body.

9. The phosphorescent organisms experimented with (certain copepods) were shown to be indifferent, in regard to movement, to light from without.

10. That light from without has another type of influence upon these phosphorescent organisms is shown, however, by the fact that their periods of activity and rest in regard to phosphorescence follow respectively the hours of daylight and darkness.

11. It is shown that this alternating diurnal periodicity can persist for a long period (twelve days) in absence of the accustomed recurring stimulus of the light and darkness of day and night.

12. The phosphorescence of these copepods in captivity is spontaneous, and although increased by mechanical stimulation, it goes on vigorously even when the organisms are undisturbed and quite still.

13. When the organisms are freshly taken, the character of the phosphorescence is such that a faint light persists, which is increased at intervals by bright flares or flashes. At a later period the light disappears entirely between the flashes, which have a longer interval between them. Under probably pathological conditions, after the organisms have been kept confined for a considerable period, there may be lighting up of the organisms with a continuous glow.

14. The appearance of the spontaneous phosphorescence at nightfall,

and its disappearance at dawn, are characterised by the same changes in a reversed order in the two cases. Before the appearance of spontaneous phosphorescence at night, and after its disappearance in the morning, there is a period of minimal excitability of about half an hour during which stirring still calls out phosphorescence. After this the organisms become completely refractory.

15. Addition of fresh water, or formol, produces, during the period in which the organism is dying, a most vivid phosphorescence, which lasts from two to three minutes, and then fades and disappears.

This display is very feeble during a daylight period, compared to what is seen after dark when spontaneous phosphorescence is present.

THE
MARINE BIOLOGICAL STATION AT PORT ERIN,
BEING THE
TWENTY-SECOND ANNUAL REPORT
OF THE
LIVERPOOL MARINE BIOLOGY COMMITTEE.

The past year has been a successful one as regards marine investigations and work in the laboratory, but a sad one otherwise, as we have lost two of the original members of our small Committee (Mr. R. D. Darbishire and Mr. Alfred Leicester) and several of our best supporters, amongst others:—Dr. E. Bickersteth, Mr. Charles W. Jones, Mr. F. H. Gossage, Mr. Robert Okell, Dr. H. C. Sorby and Mr. Horace Walker. The Committee are anxious to get some younger men as recruits to fill the places thus left vacant, both as actual workers in the field and also as subscribers to the funds. There are now plenty of students—in fact, during the Easter vacation the Biological Station has, for the last couple of years, been practically full—and there are plenty of young professional researchers; but we have very few left of the earnest amateur naturalists who were our main support twenty years ago, and of whom Mr. Darbishire and Mr. Leicester, whose loss we now deplore, were excellent examples. Both these members of the Committee were Conchologists and good Field-Naturalists, and both have written useful reports on the local Mollusca for our publications. Mr. Joseph Lomas, F.G.S., and Sir John Brunner have been recently elected to fill the two vacant positions on the Committee. In the death of Mr. Robert Okell, F.L.S., the Manx Fishery Board have lost their accomplished and devoted Secretary, who had much to do with the original negotiations between the L.M.B.C. and the Manx Government and with the erection of the present combined Biological Station and Fish Hatchery in 1901-2. His official visits, as Secretary to the Fishery Board, were frequent and helpful, and he will be greatly missed by all connected with the institution.

The dredging, tow-netting and other investigations at sea, started during the previous year with the yacht "Ladybird," have been carried on vigorously during the Easter and Summer vacations of 1908. Over 550 samples of plankton have been collected with various nets in the seas around Port Erin and have been sent to Mr. Andrew Scott for microscopic investigation. Some account of the results of these observations, so far as yet ascertained, will be found further on in this Report.

The fish hatching and the lobster hatching and rearing have gone on very much as usual this year, and about the same numbers of larvæ as before have been set free in the open waters around the Isle of Man. The details of this work are given below.

The number of visitors to the Aquarium is again between fifteen and sixteen thousand, and but for bad weather in the latter part of the season would probably have been much larger, as at the end of July the numbers were over a thousand in advance of the corresponding date in 1907.

As on previous occasions, Mr. Chadwick has supplied a "Curator's Report," which will be found below, but, in addition, I am indebted to him for some of the information given here.

THE STATION RECORD.

Thirty-eight naturalists and students have occupied the Laboratories for varying periods during the year, as follows:—

Dec. 30th to Jan. 8th.	Prof. Herdman.—Official. Dr. H. E. Roaf.—Glands of Mollusca.
April 1st to April 14th.	Miss Sowerbutts.—General. Miss Smith.—General.
April 10th to 29th.	Prof. Herdman.—Plankton.
April 16th to 30th.	Mr. W. Riddell.—Plankton.
April 16th to 28th.	Mr. W. A. Gunn.—General.
April 16th to May 2nd.	Mr. V. W. Draper.—General.
April 16th to 29th.	Mr. F. O. Mosley.—General.
April 17th to 29th.	Dr. H. E. Roaf.—Glands of Mollusca.
April 18th to 27th.	Mr. H. G. Jackson.—General.
April 18th to May 2nd.	Mr. J. Davidson.—General.
April 18th to May 2nd.	Prof. B. Moore.—Bio-Chemistry.

April 18th to May 2nd.

Miss Prescott
Miss Scott.
Miss Smith.
Miss Watterson.
Miss Southerst.
Miss Whitehurst.
Miss Cheetham.
Miss Mitchell.
Miss Moss.
Miss Stopford.
Miss Nicholls.
Miss Hirst.
Miss Owen.
Miss Kenyon.

June 11th to July 1st.	Mr. J. G. Robinson.—General.
June 12th to 15th.	Miss N. M. Stephens.—Sagitta.
June 20th to 22nd.	Prof. Herdman.—Official.
June 20th to 22nd.	Prof. Kofoid.—General.
June 24th to July 15th.	Rev. E. J. W. Harvey.—Sagitta.
July 6th to Aug. 11th.	Mr. F. H. Gravely.—Larval forms.
July 10th to 21st.	Miss K. Duffy.—General.
Aug. 3rd to 31st.	Mr. G. H. Drew.—Plankton.
Aug. 3rd to Sept. 21st.	Prof. Herdman.—Plankton.
Aug. 4th to 18th.	Mr. W. A. Gunn.—General.
Aug. 7th to 19th.	Rev. Father Van Mollé.—General.
Aug. 13th to 19th.	Mr. W. J. Dakin.—Pecten.
Aug. 15th to 21st.	Dr. J. Pearson.—Cancer.
Aug. 15th to 31st.	Mr. Burdon.—General.

Aug. 15th to 31st.	Mr. E. J. G. Alford.—General.
Sept. 14th to 19th.	Mr. R. Lace.—General.
Sept. 1st to Oct. 3rd.	Prof. B. Moore.—Phosphorescence.

The "Tables" in the Laboratory were occupied as follows:—

Liverpool University Table :—

Prof. Herdman.
Dr. Roaf.
Dr. Pearson.
Mr. Dakin.
Prof. B. Moore.
Mr. Drew.
Mr. Riddell.
Mr. Gunn.

Liverpool Marine Biology Committee Table :—

Miss Stephens.
Rev. Mr. Harvey.
Rev. Mr. Van Mollé.
Mr. Draper.
Mr. Mosley.
Mr. Robinson.
Mr. Burdon.
Mr. Alford.

Manchester University Table :—

Miss Sowerbutts.
Miss Smith.
Miss Duffy.
Mr. Gravely.

Isle of Man Natural History and Antiquarian Society Table :—

Mr. Lace.

The following students* of Liverpool University occupied the Junior Laboratory for a fortnight during the Easter vacation and worked together under the supervision of Professor Herdman, Dr. Pearson and Mr. Laurie:—

Miss Prescott.
Miss Scott.
Miss Smith.
Miss Watterson.
Miss Southerst.
Miss Whitehurst.
Miss Cheetham.
Miss Mitchell.
Miss Moss.
Miss Stopford.
Miss Nicholls.
Miss Hirst.
Miss Owen.
Miss Kenyon.
Mr. Davidson.
Mr. Jackson.

Those of us who were responsible for directing the practical work of those senior students at Port Erin were anxious that in addition to ordinary Zoological work on living material such as would supplement their University course, they should if possible make a beginning with some biological investigation requiring original observation and interpretation. So they were directed to observe and collect certain specified groups of common organisms at certain specified localities differing somewhat in their physical character—such as the two sides of Port Erin Bay, Port St. Mary and Fleshwick Bay with the view of ascertaining how far the organisms from these localities differed in number, size and other particulars. Some good work was carried out, and a beginning was made in all these respects; but much still remains to be done, and it is hoped that the students who go to Port Erin this next Easter will continue the work of their predecessors.

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* Assisted by a grant from the Liverpool Council of Education.

The Biological Station was visited during the year by Professor C. A. Kofoid, of the University of California; Mr. C. Juday, of the University of Wisconsin; Dr. J. Knight, of the Millport Biological Station; Professor W. Garstang (Leeds); Captain Creak, F.R.S., from the Hydrographer's Office; two parties of members and officials of the Lancashire County Council; and a party of members of the Natural History Society of King William's College. Two visits have been paid to the Aquarium by parties of pupils from the upper standards of the Rushen Girls' School, and one visit by the elder pupils from one of the Douglas schools.

The Committee are glad to see the institution being made use of in this manner, and they hope that other schools and educational bodies in the Island will organise periodic visits to the Aquarium, and will thus come to recognise the Biological Station as a serious educational factor which ought to be taken advantage of to the fullest extent.

Both Professor Kofoid, from the University of

California, and other visitors of high authority, have expressed appreciation of our hatching and rearing arrangements, and have represented to us that it would be very convenient to themselves and others to have published in our report a detailed description of the Hatchery and hatching boxes, with figures of the mechanism by which the water is kept in motion, that could be quoted or referred to by others wanting information or writing on such matters. Consequently I have asked Mr. Chadwick to supply me with the measurements and drawings, from which the following account of the Hatchery and its apparatus has been drawn up:—

The hatchery room measures 30 × 25½ feet, with a height of 10 feet. The concrete floor slopes slightly from the front and the back of the room to the centre, where there is a shallow gutter for waste water 6 inches wide. At the west end of the room this gutter branches at right angles to right and left, and each branch opens into a bowl-shaped depression 2 feet in diameter. From the depression on the north side of the room a deeper waste gutter runs straight through the west wall to open over a grid outside the building. A narrow groove in the floor, designed to receive the waste pipe connected with the hatching tanks, opens into each depression (fig. 7).

The ceiling is of varnished pine, and the room is lighted by six windows facing north and four facing west. The entrance from the Aquarium is on the east wall. At the opposite end of the room a door leads outwards to the path surrounding the spawning pond. On the south side of the room there is a double door opening into a wide passage leading past the engine room to the back yard. Space for four additional hatching tanks is still vacant along the south wall, the remaining space being occupied by a deep concrete (lobster) tank, built on the floor and measuring $10 \times 5\frac{1}{2} \times 3$ feet. On the left side of the west door are three shallow wooden tanks, $4 \times 2 \times 1$ feet, used for the storage of the mussels for feeding the fish. There is a circulation of sea-water through all of these tanks.

The series of eight hatching tanks, arranged in pairs, with passages between adjacent pairs, occupies the north side of the room (see fig. 7). Each tank, of wood 1 inch thick, measures 7 feet 7 inches long by 2 feet $3\frac{1}{2}$ inches wide and, over all, is 11 inches deep. It is divided into fourteen compartments, of which those at the ends are $4\frac{1}{2} \times 12\frac{1}{4}$ inches, with a semi-circular opening at the bottom of the partition. The other compartments measure $15\frac{1}{4} \times 12\frac{1}{4}$ inches: all are the same depth. At the centre of each end of each compartment is a shoot, made of sheet brass, $2\frac{3}{4}$ inches wide, $\frac{7}{8}$ inch deep and $1\frac{1}{2}$ inches long, to lead the running sea-water from one compartment to the next. Down the middle of each tank runs an iron bar (OB in fig. 3), 7 feet $6\frac{1}{2}$ inches long, $1\frac{1}{4}$ inch deep and $\frac{3}{8}$ inch thick. One end is hinged to the upper end of the tank, the other is free, and the bar is pierced at five points, measuring from hinge $15\frac{3}{4}$, $31\frac{1}{2}$, $47\frac{1}{4}$, $60\frac{3}{4}$ and $78\frac{3}{4}$ inches respectively, and into these holes are fixed short transverse iron rods $\frac{3}{8}$ inch thick and $3\frac{3}{4}$ inches long. The bar carries two leaden weights, of $3\frac{1}{8}$ lbs. each, grooved so as to slide at the free end. The bar in working up and down (see fig. 3, Gd) is guided by an iron, 1 inch wide 8 inches long, shaped like a tuning fork and fixed $18\frac{1}{2}$ inches from the lower end of the tank. The inside of the tank is coated with a mixture of tar and pitch, applied hot. Each tank rests on three trestles and is 22 inches above the floor at the upper end and $19\frac{3}{4}$ inches at the lower one.

Each of the ten larger compartments in a hatching tank contains a hatching box made of wood $\frac{5}{8}$ inch thick and measuring $12\frac{1}{2} \times 11\frac{1}{4} \times 9\frac{5}{8}$ inches. The bottom is made

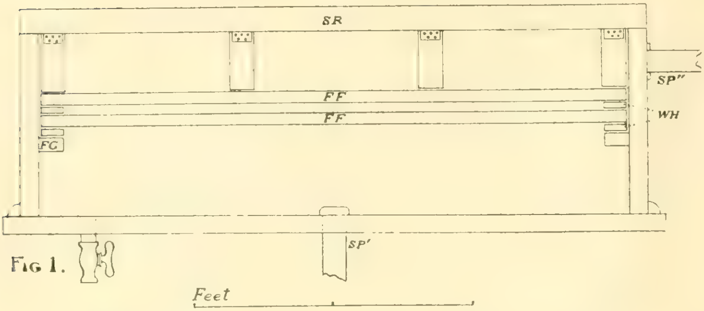


Fig 1.

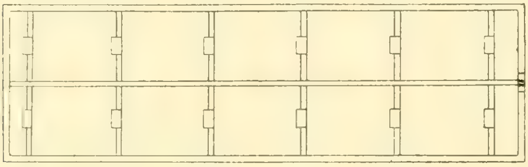


Fig 2.

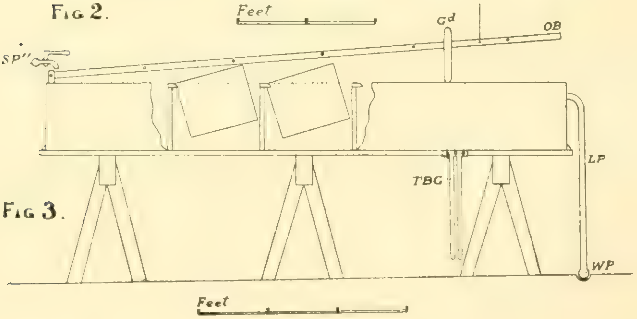


Fig 3.

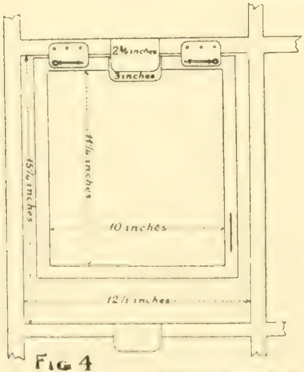


Fig 4

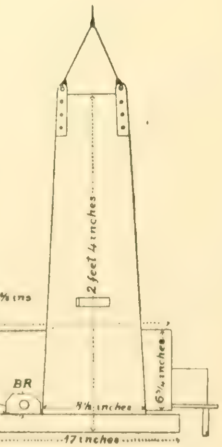
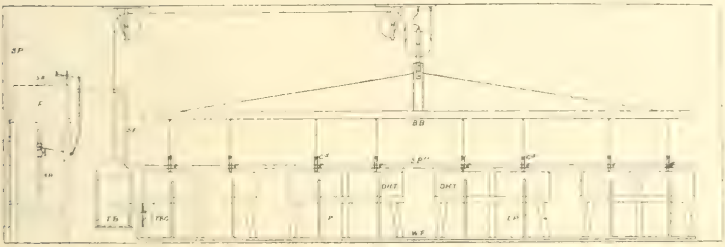


Fig 5.

Fig. 6.



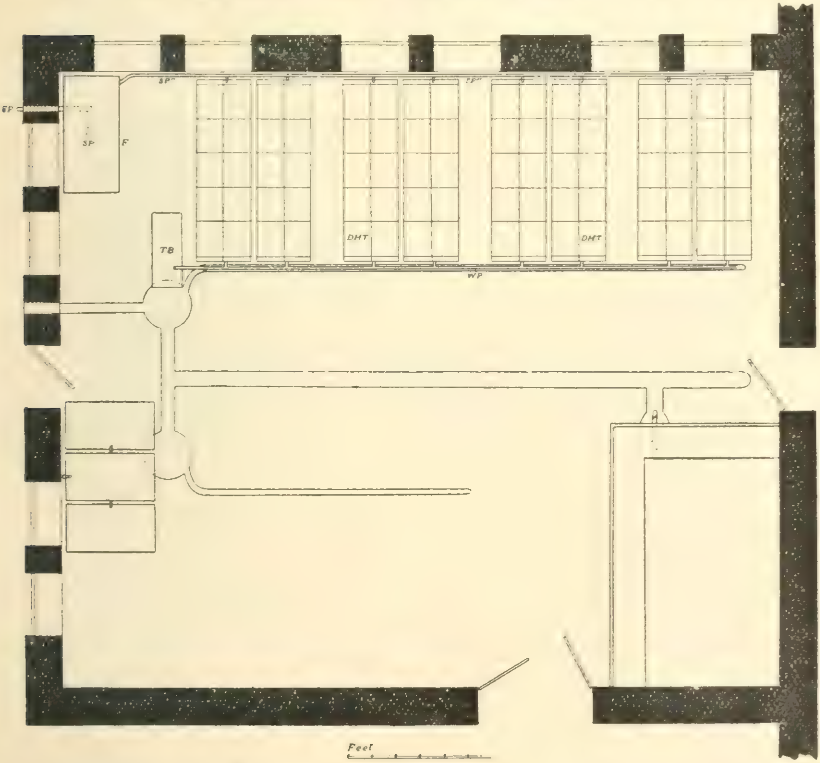


Fig. 7.

FIG. 1. Sectional view of filter-box.
FIG. 2. Hatching tank, seen from above.
FIG. 3. Side view of hatching tank, showing two boxes in position, with oscillating bar raised.
FIG. 4. One compartment of hatching tank, with box hinged in position, seen from above.
FIG. 5. Side view of tipping-box and frame.
FIG. 6. Elevation of filter, tipping box, hatching tanks, and oscillating apparatus.
FIG. 7. Ground plan of hatchery and tank. Same scale.

of barked bolting silk, having about 40 threads to the inch. In the centre of one end of the box is a shoot made of sheet brass 3 inches wide, $\frac{7}{8}$ inch deep and $1\frac{1}{2}$ inch long. This fits below the shoot in the transverse partition between the compartments of the tank, to which the hatching box is attached by two leather hinges fastened with copper tacks. A short length of brass wire, with the ends bent at right angles, is driven into the top edge of each box which is nearest to the longitudinal partition. This wire receives the corresponding transverse rod of the hinged iron bar, when the latter falls for the purpose of depressing the floating box. (See the figs.).

The supply of sea-water passes from the large outside storage tanks (see photograph, fig. 8) through a 2-inch galvanised iron pipe, which enters the building at the north-west corner (SP in the figures). From thence a $1\frac{1}{2}$-inch pipe carries the supply to the aquarium and laboratories, and from this a branch of the same size (SP′) supplies the hatchery. Here the water first enters the filter. This is a box made of wood $1\frac{1}{2}$ inches thick, and coated inside with a mixture of tar and pitch. Its length over all is 4 feet 6 inches, width 2 feet 4 inches, and depth inside 1 foot 4 inches. At a depth of 9 inches from the top a flange of wood, 2 inches wide and 1 inch thick, runs round the inside of the box, and resting immediately on this is a rubber washer of the same width as the flange and $\frac{1}{4}$ inch thick. Upon this rests a frame of wood 4 feet 3 inches long, 2 feet $\frac{3}{4}$ inch wide and 1 inch thick, and strengthened by two equidistant cross pieces. To this frame five thicknesses of white Turkey towelling are fastened with $\frac{7}{8}$ inch copper tacks about 1 inch apart all the way round, and a corresponding length of galvanised wire netting of $\frac{1}{2}$-inch mesh is fastened over the towelling to keep it in place. Above the frame is another rubber washer and then a second similar frame. A spar of wood, 4 × 2 inches (SR in fig. 1), rests on the top of the box and is securely braced to the ends. To its lower face are hinged four pieces of hard wood, $6\frac{1}{2} \times 2\frac{1}{2} \times 1\frac{1}{4}$ inches, at distances corresponding to the ends and cross bars of the filter frames. When these hang vertically their rounded ends are firmly pressed against the frames, and the pressure can be increased by the interposition of thin wedges of hard wood. Water is admitted to the filter through the valve in the supply pipe SP′, and the flow is regulated by a butterfly valve immediately above, the movements of which are controlled by a ball-tap arrangement, the details of which will be readily understood by reference to fig. 6. After passing through the filter frames the water leaves the filter box through the $1\frac{1}{2}$-inch pipe SP″ and is distributed to the hatching tanks, where it flows downward from compartment to compartment, so as to fill and surround the floating boxes containing the ova. From the lower end of each hatching tank it flows through a lead pipe of 1 inch bore (LP) to a $1\frac{1}{2}$ inch

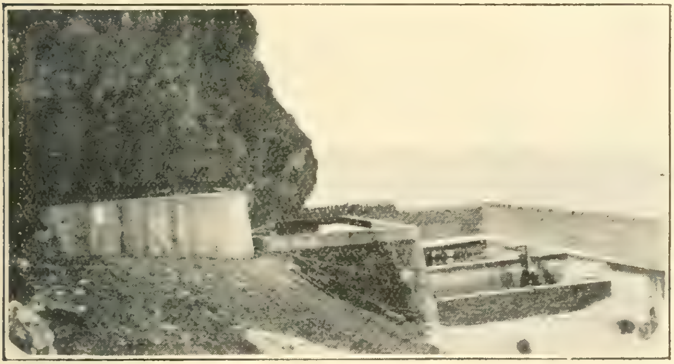


FIG. 8. The fish-pond, and the two large outside storage tanks—photographed from the cliff behind the station.

galvanised iron one (WP), laid in a groove in the concrete floor, by which it is carried to the tipping box (TP). The dimensions of the tipping box are given in fig. 5. It is a wedge-shaped box made of wood $\frac{3}{4}$ inch thick and coated inside with a mixture of tar and pitch. The bearings (BR) upon which it works are of lignum vitæ, and are screwed to the base of the frame which carries it. The bushes are of brass. At the back of the box is a small shelf, upon which rests a small box containing lead weights, and underneath the shelf a piece of wood 4 inches long projects in such a way as to touch the floor when the tipping box is full of water, and so give the initial move in tipping over. The side of the tipping box frame nearest to the first hatching tank has a piece of bar iron 11 inches long and 1 inch wide projecting from it. This passes between the prongs of two guides, the outer of which is shown in figs. 3 and 6, TBG. The inner prong is smaller and is underneath the tank. The object of this is to keep the tipping box parallel with the side of the hatching tank when it is at work.

The frame in which the box works is suspended by one end of a length of wire rope $\frac{3}{16}$ths inch thick. This passes over a pulley of hard wood, 12 inches in diameter, which works in a frame of iron firmly bolted to the ceiling immediately above the box. It then passes over another pulley of the same size and under a third, to be finally secured to a ring in the ceiling. The frame in which the third pulley works is belted to the short stem of what is called the balance beam (BB in fig. 6), a piece of wood 23 feet long, $1\frac{1}{2}$ inches wide × $1\frac{1}{2}$ inch thick. The ends of the beam are supported from the stem by $\frac{3}{8}$-inch iron rods. From the balance beam the oscillating iron bars of the hatching tanks (OB) are suspended by means of brass wire. As a precaution, the upper end of the frame of the pulley attached to the balance beam is secured to the ceiling by means of a short length of rope, so that in case of breakage of the wire rope the beam would still remain suspended (see fig. 6).

When the apparatus is in action, the water which has passed through the hatching tanks into the waste pipe (WP) is poured into the tipping box. As the latter fills, its weight gradually lowers the box and so raises the balance beam and the suspended oscillating iron bars, and the floating boxes in the compartments of the hatching tanks rise by their own buoyancy as they are released from the weight of the bars. When the tipping box is nearly full (the precise moment is regulated by the weights in the small box at the back) it tips over and empties its contents into the circular depression in the concrete floor, from which the water escapes by means of the gutter to the drain outside the building (see ground plan). The moment the tipping box is empty the weight of the balance beam and the suspended oscillating bars comes into play, and the former falls until the latter lie parallel with the longitudinal partitions of the tanks and so depress the hatching boxes by means of the short transverse iron rods. The tipping box fills and empties about four times in five minutes.

When the hatching boxes (see figs. 3 and 4) are depressed in the compartments of the tanks, the sea-water is forced upwards through the meshes of the bolting silk, so as to cause ascending currents which keep the fish eggs or embryos suspended in the water and prevent them from accumulating on the bottom or stagnating on the surface. This mechanical device for giving an intermittent vertical motion to the water in the hatching boxes—apart from the gentle horizontal flow from compartment to compartment—is actuated solely by the weight of the waste water from the tanks filling the tipping box which periodically empties. It has proved, as the result of six years' working, to be very effective in hatching such sea-fish as the plaice; and is also suitable for maintaining the "berried" adult lobsters and the newly hatched young in a healthy condition. At other times of the year, when not required for fish, the hatching tanks have been used on occasions for keeping invertebrata such as Hydroids, Polyzoa, Echinoderms, Tunicata and Mollusca in a healthy condition temporarily while under observation or while awaiting investigation. This mechanism would probably also be well adapted for rearing experiments with delicate invertebrates which require some vertical movement in the water; and, in fact, will be found to be useful in biological stations in general apart from fish-hatcheries.

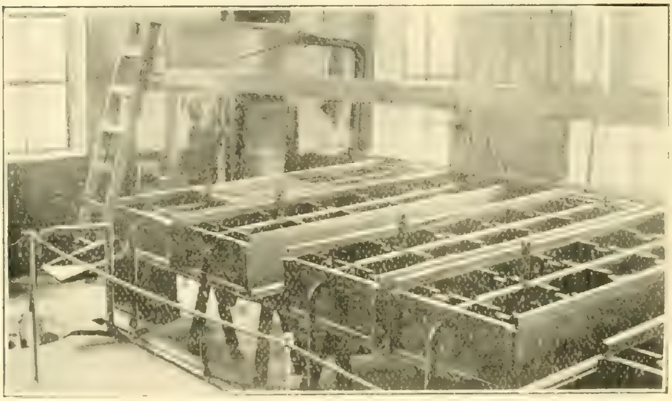


FIG. 9. The hatching tanks when used for rearing lobsters in summer.

CURATOR'S REPORT.

Mr. Chadwick reports as follows:

"I am again able to record a year of progress in all departments of the work of the Station. Even in that of the fish hatchery the results were better than the subjoined figures indicate, seeing that our stock of spawners was smaller than that of any recent year. The increase in the numbers of workers in the laboratories is slight only, but again much good work has been done by students, and researches have been continued by Dr. Roaf, Professor B. Moore, Dr. Pearson, and Messrs. Gravely and Dakin.

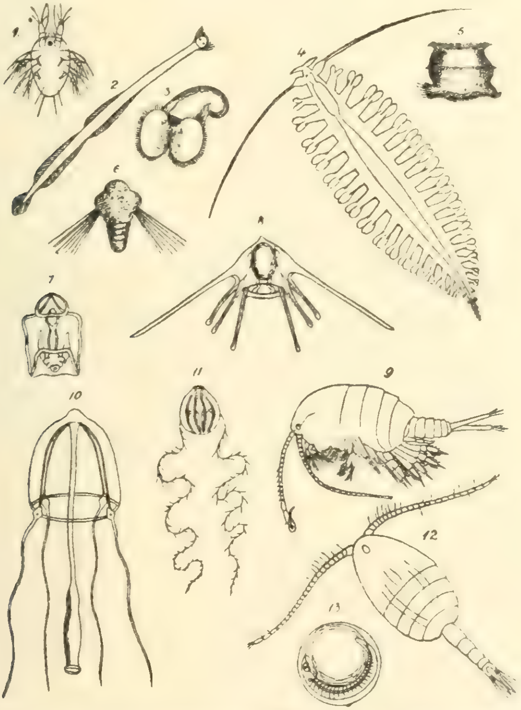


FIG. 10. A general gathering of Plankton, or floating organisms caught in the tow-net; No. 11 is *Pleurobrachia* (nat. size).

Plankton work has figured still more largely than last year, and more of the Curator's time has been devoted to it. In this connection it may be mentioned that the Ctenophoran *Pleurobrachia pomiformis* was exceptionally abundant during the prevalence of hot weather at the end of June and the beginning of July (see fig. 10).

I have very little of a faunistic character to record. The sea-hare, *Aplysia punctata,* was exceptionally common in the rock pools in spring and early summer, and two divers in the employ of the Harbour Commissioners, who examined the moorings of the buoy at the end of the breakwater on July 3rd, reported to me that sea-hares were abundant on the sandy bottom around the moorings. The largest specimen I have seen of our local Octopus, *Eledone cirrosa* (fig. 11), was brought in by a fisherman in March. Its dimensions, taken immediately after death, were as follows: Total length, 22 inches; length of left inner arm, 14 inches; length of body from between the eyes to the apex, 7 inches; width of head between the eyes, 3 inches.

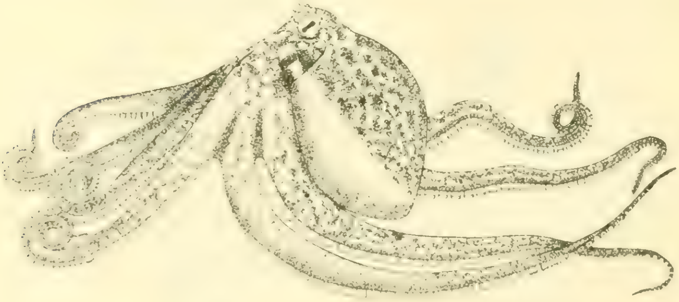


FIG. 11. Our local "Octopus."

As in former years, numerous ephyrae of *Aurelia aurita* appeared in the spawning pond in January and February, and I took the opportunity of counting the number of tentaculocysts of 800 specimens, with a view of ascertaining the numerical variation. The result was as follows:—

2	had	4	tentaculocysts	...	13	had	12	tentaculocysts
7	,,	6	,,	...	8	,,	13	,,
30	,,	7	,,	...	3	,,	14	,,
594	,,	8	,,	...	1	,,	15	,,
32	,,	9	,,	...	1	,,	16	,,
20	,,	10	,,	...	1	,,	18	,,
38	,,	11	,,	...				

Twin tentaculocysts occurred in one specimen with a total number of 4, in one with 7, in two with 8, in one with 10, in one with 11, and a triplet of tentaculocysts in one with 16.

The number of volumes in the library continues to increase slowly. Several valuable additions, for which our thanks are due, have been made by the executors of the late Mr. Robert Okell, and a few have been purchased. I have devoted such time as I could spare from more pressing work to the preparation of a card catalogue, but here again progress is slower than the importance and usefulness of such a catalogue demands.

The Aquarium has again attracted over 15,000 visitors, and had not the weather been so inclement during the months of August and September this number would have been largely exceeded, the total at the end of July being more than 1,000 in excess of the corresponding period of 1907. The tanks have been kept well stocked and in excellent condition, but, in the absence of dredging and trawling in the deeper waters of the neighbourhood, no organisms of special interest have been added. The number of copies of the "Guide to the Aquarium" sold, over 830, is not quite so large as that of last year.

The continued growth of organisms, especially *Sabella penicillus* and *Mytilus edulis,* in the circulation pipes has given me much concern during the year. The tubes of the former and the byssus fibres of the latter occasionally become detached and are carried along by the stream of water until a tap is reached, and the supply of water to the tank below is obstructed. The calcareous sponge, *Leucosolenia botryoides*, now grows in quantity on the walls of certain of the tanks.

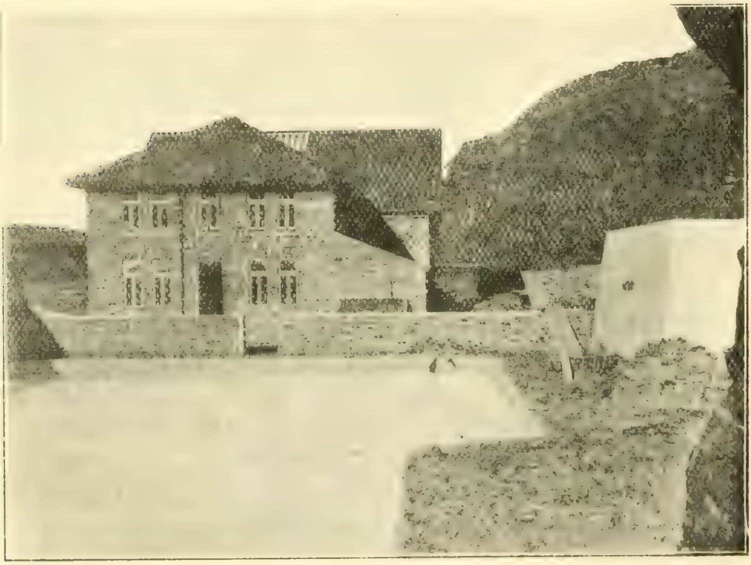


Fig. 12. The spawning ponds.

Considerable difficulty was experienced during the autumn of 1907 in collecting adult plaice for spawning purposes. Of the 220 which supplied all the eggs hatched this year 190 were caught in our own trammel nets, the remainder being added by the Assistant Curator while on a trip in Mr. R. Knox's steam trawler "Lady Loch." All these fish were maintained in a healthy condition throughout the winter, and it is satisfactory to record that, in spite of a high percentage of unfertilised eggs, the number of larvæ hatched is substantially larger than that of last year. The majority of these larvæ were set free, as usual, by Professor Herdman from the yacht "Ladybird" in the open sea a few miles clear of the Isle of Man.

Efforts were renewed in July and August to hatch and rear larvæ of the common lobster, but I regret to be unable to report greater success than in former years. The supply of female lobsters with nearly ripe eggs was again small, only 20 being brought in by the local fishermen, and the old difficulty—cannibalism amongst the larvæ—was severely felt, in spite of an abundant and varied supply of food. Experiments in rearing the larvæ were made with large canvas bags, supported on frames of wood, which were placed in the spawning pond, and the water therein abundantly aerated with streams of water from the aquarium and hatchery, but the results were not encouraging. However, over 3,000 larvæ in various stages of development and including a few well-grown lobsterlings were set free in the sea; and we hope to adopt new lines of experiment during the ensuing season which may give better results.

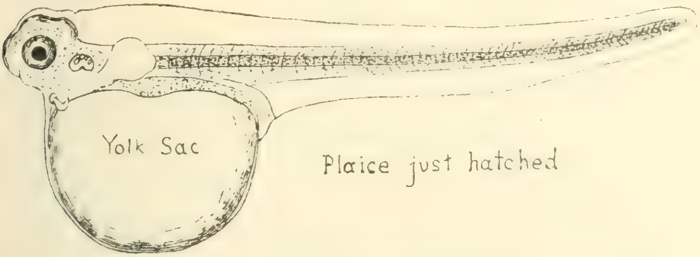


FIG. 13. Larval plaice. × 15.

The approximate numbers of plaice eggs collected, and of the young fish set free upon the dates specified, are given in the following table:

Eggs collected.		Date.		Larvæ set free.		Date.	
4,000	...	Mar.	7	3,000	...	April	2
50,000	...	,,	11	43,000	...	,,	2
25,000	...	,,	12	17,500	...	,,	2
36,000	...	,,	13	25,500	...	,,	2
15,000	...	,,	16	5,000	...	,,	2
70,000	...	,,	17	54,000	...	,,	8
89,500	...	,,	18	72,000	...	,,	8
62,000	...	,,	19	25,000	...	,,	10
132,000	...	,,	20	79,000	...	,,	10
80,000	...	,,	21	54,000	...	,,	11
294,000	...	,,	23	241,000	...	,,	11
73,500	...	,,	24	59,000	...	,,	11
42,000	...	,,	25	32,500	...	,,	13
283,000	...	,,	26	252,000	...	,,	13
126,000	...	,,	27	116,000	...	,,	15
327,000	...	,,	28	180,000	...	,,	15
149,000	...	,,	30	115,500	...	,,	20
309,000	...	April	1	220,000	...	,,	20
408,000	...	,,	2	351,000	...	,,	22
75,500	...	,,	4	44,000	...	,,	23
519,000	...	,,	6	446,000	...	,,	23
263,000	...	,,	7	195,000	...	,,	27
278,000	...	,,	8	184,000	...	,,	27
73,500	...	,,	9	52,000	...	,,	27
247,000	...	,,	11	173,000	...	,,	30
71,000	...	,,	13	54,000	...	,,	30
168,000	...	,,	14	136,000	...	May	2
100,000	...	,,	15	79,000	...	,,	2
144,000	...	,,	18	97,000	...	,,	7
85,000	...	,,	20	57,000	...	,,	7
74,000	...	,,	21	47,000	...	,,	7
110,000	...	,,	22	74,000	...	,,	15
136,000	...	,,	23	63,000	...	,,	15

Eggs collected.		Date.		Larvæ set free.		Date.	
67,000	...	April	24	46,000	...	May	15
32,000	...	,,	27	11,000	...	,,	15
78,000	...	,,	29	45,000	...	,,	15
5,096,000				3,748,000			

These figures show some advance on last year, and as the stock of spawners (over 400) in the ponds this winter is considerably larger than before we have great hopes the coming hatching season will show a still greater advance."

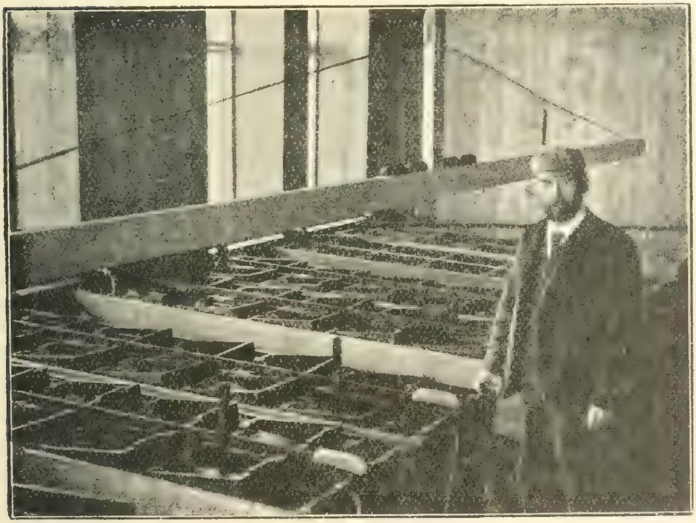


FIG. 14. Mr. Chadwick in the fish hatchery.

Mr. Gravely's Report.

Mr. F. H. Gravely, Demonstrator of Zoology in the University of Manchester, who occupied the Work-Table of that University during a considerable part of July and August, has sent me the following note upon some of the observations made in the course of his work:—

"The most striking feature of the animal life between tide-marks at Port Erin during July this year (1908) was its remarkable scarcity; this was the more noticeable after its unusual luxuriance last year. I again visited the colonies of *Tubularia indivisa*, var. *obliqua*, at Port St. Mary; only a single hydranth could be obtained that bore any gonophores; these, however, were female and all of the '*obliqua*' type. In connection with these I ought to correct one statement in my last year's report: there is no histological difference—except such as is connected with the absence of radial canals—between the male gonophores of this variety and those of the normal *T. indivisa*. My failure to find the 'conspicuous sterile cells in the outer layers of sperm' in the normal gonophores was due to the fact that the only specimens of these gonophores, that I had then seen sections of, were not sufficiently well preserved to show them.

"Since the last report was sent in I have made a special study of the gonophores of *Tubularia larynx* from the neighbourhood of Port Erin, and can now state what I only suspected then: that all the hydranths I collected last year, both from the breakwater and from the Calf Sound, are hermaphrodite; and, further, that a single gonophore even not infrequently shows spermatogenesis going on at the same time as oogenesis and embryonic development. Although every specimen I have found at Port Erin shows this condition, those from other localities appear to be diœcious, as they have always been believed to be. Apart from these, no case of hermaphroditism amongst hydroids is known, with the exception of a few isolated instances mentioned as monstrosities by persons who have had to examine very large numbers of some one species.

" *Haliclystus* was again found both on the breakwater and at Fleshwick Bay. Port Erin Bay was frequently visited this summer by large shoals of Medusae *Aurelia*, *Cyanea*, *Melicertidium*, *Turris*, *Tiara*, and *Margelis* all being very abundant on several occasions

" The tow-nettings proved to be quite as good as last year. Tornaria was fairly common again, and the shear-net discovered numerous specimens of the later stages for us. Pilidium and Actinotrocha, especially the former, were unusually abundant during the last fortnight of July. A new Ophiopluteus was taken several times early in August, but I have been unable to find any description of it as yet; its most striking peculiarity is the special development of the ciliated bands at the bases of the arms to form conspicuous ridges, recalling the 'epaulettes' of an Echinopluteus. '*Ophiopluteus mancus*,' usually the commonest Ophiopluteus at Port Erin at this time of year, was extremely rare, but the larvæ of *Ophioglypha albida* were much more abundant than last year, and those of *Ophiothrix fragilis* were also very common.

" A specimen of *Eledone*, which had died in the Port Erin Aquarium, recently sent to Manchester, was found to have its suckers arranged in a double row on each arm. Dr. Hoyle called my attention to this striking resemblance between this specimen and the genus *Octopus*. In other respects, however, it resembled *Eledone*, and an examination of the radula has proved it to be undoubtedly a specimen of this genus. I expect to publish shortly a more detailed account of the occurrence of double rows of suckers on the arms of *Eledone* from Port Erin, together with an account of the spawning of *Eledone* that took place in the aquarium this summer. (See Memoirs Manchester Literary and Philosophical Society)."

FURTHER NOTES ON WORK.

Professor Benjamin Moore has continued his interesting observations on the reactions of minute swimming organisms to light and other forms of stimulation. These have led on to an investigation of the phenomena of phosphorescence, which Professor Moore has made the subject of his presidential address to the Biological Society, printed in this volume. One of the most interesting points he has determined is that a diurnal periodicity is present, the organisms becoming luminous on stimulation at night, but refusing to do so during the day, even when kept in a dark room.

Dr. H. E. Roaf continued his investigations on the digestive processes of lower marine animals. He prepared glycerine extracts from the digestive glands of various invertebrates; and then proceeded to test these extracts for digestive (hydrolytic) enzymes by investigating their action on various food stuffs. The digestion of carbohydrates and fats by these extracts was found to be almost universal. The digestion of proteins also occurred, but requires some further investigation. Rennin-like enzymes were found, and several of the extracts appeared to cause coagulation of mammalian blood-plasma. The full results of this research are being published in the "Bio-Chemical Journal" for 1908.

The investigation, by means of the dredge and the trawl, of the three fishing banks the Ballaugh, the

Train and the Wart—lying in the Coralline zone to the west of the Isle of Man, has not made much further progress during the past year. A few additional hauls have been made on each bank, but the unsettled weather during this summer has been very unfavourable for such work. The lists are not yet sufficiently complete to form the basis of any comparison; but the work will be continued as opportunity offers, and I hope to return to the subject in a future report.

During August, Mr. Harold Drew, of Christ's College, Cambridge, now Lecturer on Biology at the Plymouth Technical School, acted as my Sea-Fisheries Assistant on board the yacht, and gave most efficient help in gathering, preserving and measuring the plankton samples, and in taking sea-temperatures and other observations. On several occasions we took serial temperatures with the Negretti and Zambra reversing thermometer, and samples of the sea-water with the Mill water-bottle, at a couple of points (Stations A and B) in mid-channel, down to depths of 60 and 70 fathoms. These and the other water samples have since been analysed by Mr. Drew at Plymouth, and in returning me the figures for the salinities, &c., he remarks as follows:—

"You will notice that there appears to be a complete reversal of conditions between August 24th and September 12th. On August 24th, the water of lowest salinity is at 62 fathoms, and the water of highest salinity at 20 fathoms, and from 20 fathoms to the surface there is a slight decrease, but the general condition may be taken as high salinity above and low salinity below.

"On September 12th, the water of highest salinity is below and of low salinity above. There appears to have been an inflow of cold, high salinity water along the bottom. The difference between temperatures of the bottom samples is well marked, and is much more than would be accounted for by the difference of the surface temperatures.

"I think the hydrographical conditions in the neighbourhood would be of great interest if more frequent observations could be taken."

In three out of four series of temperatures taken by Mr. Drew and myself on August 17th, August 24th, and September 12th, the highest temperature was found to be near the bottom at a depth of between 50 and 74 fathoms, but in the fourth series the coldest water was at the bottom.

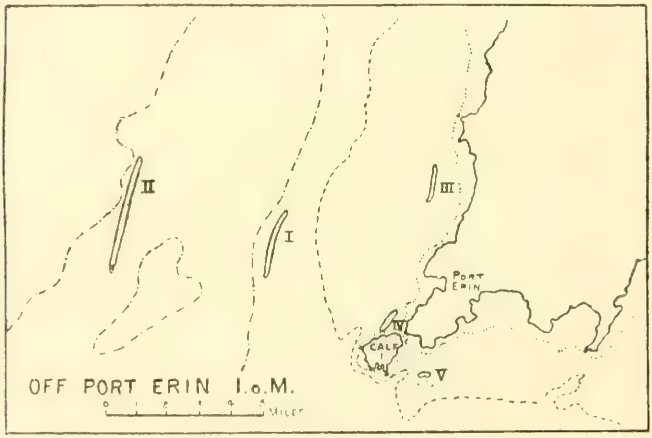
I think Mr. Drew and I are agreed, however, that these observations are too few and sporadic to draw conclusions from. Moreover, I wish to repeat the observations more systematically with other water-bottles and other reversing thermometers. I have since obtained, for use on the yacht next season, the Buchanan-Richard water-bottle, as used by the Prince of Monaco, and the Ekman water-bottle, supplied by the International Central-laboratory at Christiania, and two of the International reversing thermometers made by Richter of Berlin. So it will now be possible to try three different water-bottles and three reversing thermometers against one another and compare results.

Mr. Drew has also kindly examined for relative alkalinity some samples of sea-water from our storage tanks, the Aquarium outflow and the fish-pond. The very marked reduction of alkalinity which he finds in the water of the pond he considers to be probably due to the presence of filamentous Bacteria and Algae, which increase greatly during the late summer. These are removed when the pond is cleaned at the end of September preparatory to the spawning season. Mr. Drew adds to the above, which he has seen in proof: "A slight but definite reduction in alkalinity was found in the water from the Aquarium outflow, produced during the passage of water through the tanks. This emphasises the fact that in an Aquarium such as that at Port Erin, where water is only allowed to circulate once through the tanks, natural conditions are much better approximated than in Aquaria where the same water is pumped again and again through the circulation, thus steadily diminishing in alkalinity with each passage through the tanks. Port Erin enjoys nearly unique advantages in this respect, the water being naturally so clear that there is no need for a large storage and precipitation tank."

Plankton Investigations at Port Erin.

In continuation of the work reported upon last year, Mr. Andrew Scott and I published in the "Lancashire Sea-Fisheries Report," in May, 1908, a full and detailed account of the investigation of nearly 900 gatherings taken in the year 1907 in the northern portion of the Irish Sea, and of which about 650 are from a limited area in the immediate neighbourhood of Port Erin. At the south end of the Isle of Man, where these gatherings were taken, there are very important fishing grounds, which are frequented by trawlers from Lancashire and from Ireland, as well as by the Manx fishermen. This, as well as the circumstances that we have there, within a few miles, a sheltered sandy bay, an exposed rocky coast, a narrow strait through which strong tides run, and an area of open sea with depths reaching to 70-80 fathoms, has led me to consider Port Erin a very suitable locality for a thoroughly exhaustive or intensive study of the Marine Plankton. I propose to give here a short summary of our main conclusions, as published, and a comparison with the results for 1908, so far as these are yet known.

I think it desirable to point out here that the sea off Port Erin cannot be regarded as an exceptional locality. The narrow strait known as the Calf Sound (IV on map below), where the tidal currents run with great velocity is, no doubt, exceptional in some respects; but the open sea, five to ten miles off land (I and II on map), has no physical peculiarities such as would lead us to expect any unusual distribution of organisms.



It may be useful to repeat here the same little map that I used last year in order to show the localities at which the gatherings were taken. The nets used, it will be remembered, were: Two closing vertical nets, the Nansen and the Petersen-Hensen, a weighted and two surface, open, horizontal tow-nets, all made of No. 20 bolting silk; and, in addition, a coarser silk tow-net (No. 6 silk) and a large-meshed shear-net (see fig. 15) only used occasionally.

In the summer of the present year (1908) we used, in addition, another surface tow-net suspended from a pulley in such a manner that in a rough sea a few yards of line could be let out during the strain of a wave and recovered again when slack, so as to keep the pull on the net about constant. We also used on occasions the small fish-net, or "yngel-trawl," of Petersen (fig. 16), which

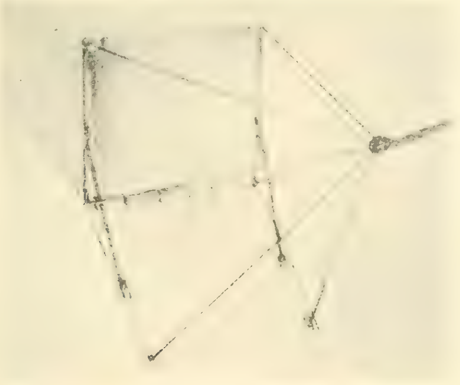


Fig. 15. The mouth of the "shear-net."

Fig. 16. "Yngel-trawl," with "otter-boards": *a*, mouth.

obtained much the same kind of catches as the shear-net.

During the Easter vacation of 1908 (April 11th to 29th inclusive) I took 186 gatherings, in 15 working days (an average of over 12 per day), which will serve to compare with those taken during the corresponding period of 1907. The number of Diatoms does not appear to be so great this year as in 1907. The spring maximum does not reach to such a height, and is certainly much later than was the case last year. Looking first at the volumes of the catches, the monthly average in cubic centimetres for the first four months of the year 1908 is as follows: January, 0·8; February, 0·6; March, 1·8; April 7·4; showing an increase in March, which became still more marked in April, but is small compared with that in 1907. The average haul during April, 1908, with the different nets used is:—

Hensen.	Nansen.	Surface (No. 20).	Surface (No. 6).	Weight-net.	Surface (Bay).	Shear.
0·6	1·42	2·77	3·45	4·18	5·5	15

Showing much the same proportions between the nets as in the previous year, but smaller numbers throughout.

In 1908, however, the catches of Diatoms continue relatively high throughout May and June and then drop rapidly in July and August. The curve for the total plankton seems, so far as our examination of the results has gone, to follow much the same course. The maxima in the various groups seem all to be later, and less marked, in 1908 than they were in 1907.

In the summer of 1908 I took 268 gatherings in the sea off Port Erin in 27 days, which, with Mr. Chadwick's weekly gatherings in Port Erin Bay during the remainder of the year, will bring the total for 1908 up to about 560, in addition to the samples taken by the Lancashire Sea-Fisheries steamer during her periodic cruises. Mr. Scott and I are still engaged in examining and discussing the summer gatherings, but so far as we have gone there seems no doubt that all the gatherings in 1908 were, on the average, smaller than in 1907, and that there was no marked Diatom maximum this last autumn. In 1907 there was a marked Diatom rise during the last few days of September (fig. 17), due in the main to the great abundance of *Rhizosolenia semispina*, while in 1908 the catches remained small and of the usual summer type until far on into October. It is only on October 15th and 16th that we notice any marked increase in the number of Diatoms in the gatherings, and even then it is not comparable with the phenomenon of the previous autumn. The Diatom *Thalassiosira nordenskioldii*, which was so abundant in 1907, was very poorly represented this year; while some of our 1908 collections have been unusually rich in Peridinians. Noctiluca (fig. 18), has been unusually abundant this autumn. Mr. Scott collected a pure sample of 150 c.c. on September 25th, at Piel, and estimated that there were then two millions per gallon in the water of the Barrow Channel.

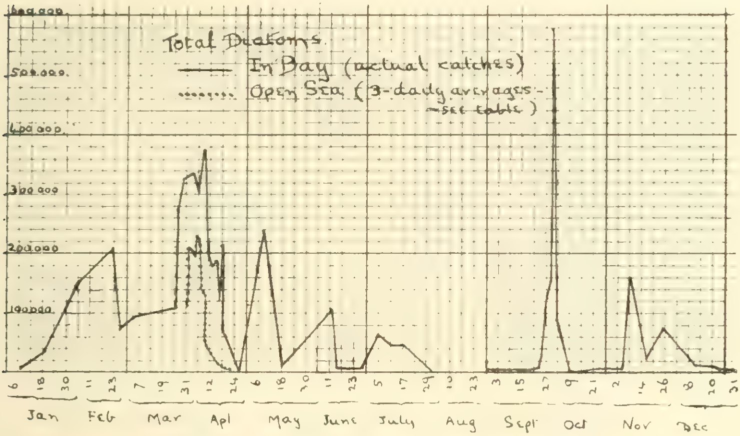


FIG. 17. Curve for total Diatoms in 1907.

I now turn to some of the conclusions that were drawn in the last Sea-Fisheries Report from a study of the detailed figures for 1907; and I shall illustrate them by a few diagrams which were used in a Presidential address to the Linnean Society last May. The blocks have been kindly lent by the Council of that Society.

It is clear that some of the great seasonal variations in the plankton are not due to changes in the sea-water such as are recognised in hydrographic observations, but are caused simply by the normal sequence of stages in the life-histories of organisms throughout the year. No amount of "hydrographic" change in the water will determine the presence of Echinoderm larvæ at a time of year when they are not produced, nor of Crab Megalopas when they do not naturally occur.

Three factors, at least, contribute to the constitution of the plankton from day to day throughout the year:—

(1) The sequence and periodicity of stages in the life-history of the organisms;

(2) Irregularities due to the inter-action of organisms, as when one group serves as the food of another;

(3) Periodic changes and abnormalities of either time or abundance caused by the nature of the sea-water or by weather conditions which may either determine or prevent the normal or permit of an abnormal development of certain species.

The appearance of swarms of Balanoid Nauplii, followed after an interval by the "Cypris" stage, is an example that comes under the first head. The disappearance of Diatoms when used as food by the increasing swarms of Copepoda and other Crustacea, both larval and adult, and of the Copepoda in turn when eaten by the developing post-larval fish, are changes falling under the second head. The great increase in the number of Diatoms in spring, when the physical condition of the sea-water has become favourable, the enormous development of Dinoflagellates which may take place suddenly in autumn under unusual weather conditions, the almost total suppression of a group such as the Medusæ in some localities in an unusually stormy summer, and the immigration of a species or a group of species from the open ocean or from a neighbouring sea-area as the result of variations in the hydrographic conditions, are all examples that may be classed in the third category.

Two or all of these factors may, however, be at work together, and so the explanation of any particular change may be a very complicated problem. The increased development of a group, or the immigration of a species, may so disturb the balance of nature as to be followed by unusual changes in other groups.

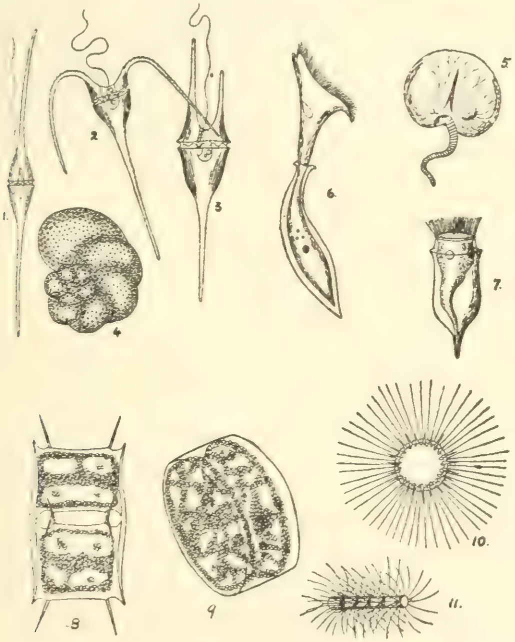


Fig. 18. Protozoa and Diatoms (highly magnified).
1–3, Dinoflagellates; 5, *Noctiluca*; 8–11, Diatoms.

The results of the hauls obtained on April 9th and 10th in Port Erin Bay are good examples of a local plankton mainly composed of Diatoms. It is noticed in running the eye down the groups that whereas the Diatoms occur in thousands, extending up to even 100,000, the Dinoflagellates are in hundreds, extending, at most, to a thousand; the Copepoda are in tens, rarely reaching a hundred or two, while the fish-eggs are scattered units, such as 1 and 2. The general character of the hauls on April 9th is that there are ten times as many Copepods as fish-eggs; ten times as many Dinoflagellates as Copepods, and ten times as many Diatoms as Dinoflagellates, per species. On the following day, April 10th, the proportions are somewhat the same, and if we pick out the largest numbers recorded in each of these groups these may be described in the case of each day as units, hundreds, thousands, and tens of thousands, or thereabouts. (See fig. 18).

	Diatoms.	Dinoflagellates.	Copepods.	Fish-Eggs.
April 9	100,000	1000	250	2
April 10	90,000	2000	780	8

Very much the same relations were found to obtain about the middle of April, 1908.

As another example of the same run of figures in these groups we note that in a surface haul W. of the Calf Island, on March 29th, the total

Diatoms	amount to	...	72,650
Dinoflagellates	,,	...	3,500
Copepoda	,,	...	363
Fish-Eggs	,,	...	93

Generally speaking, these proportions hold good for many of the series of hauls not only in the Bay, but also from the open sea outside. Fig. 19 shows by the proportions of the black squares the numbers of individuals contained in the greatest hauls of Diatoms, Copepods, Dinoflagellata, Oikopleura, and Sagitta respectively.

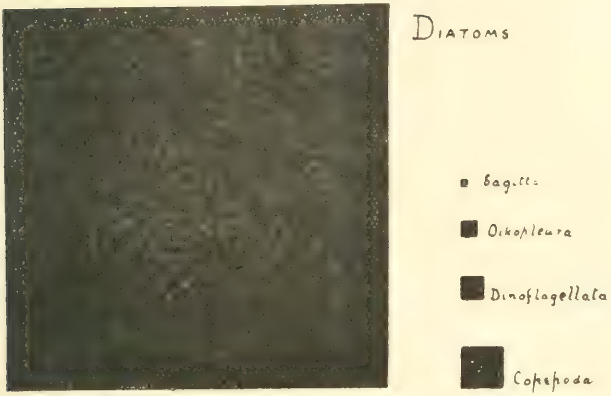


Fig. 19. Diagram showing maximum hauls in the year 1907.

Lists compiled from the gatherings and curves drawn from these lists show that, as a consequence of the three factors noted above, certain groups and certain prominent species differed from one another greatly in their relative abundance throughout the months of the year (see fig. 20).

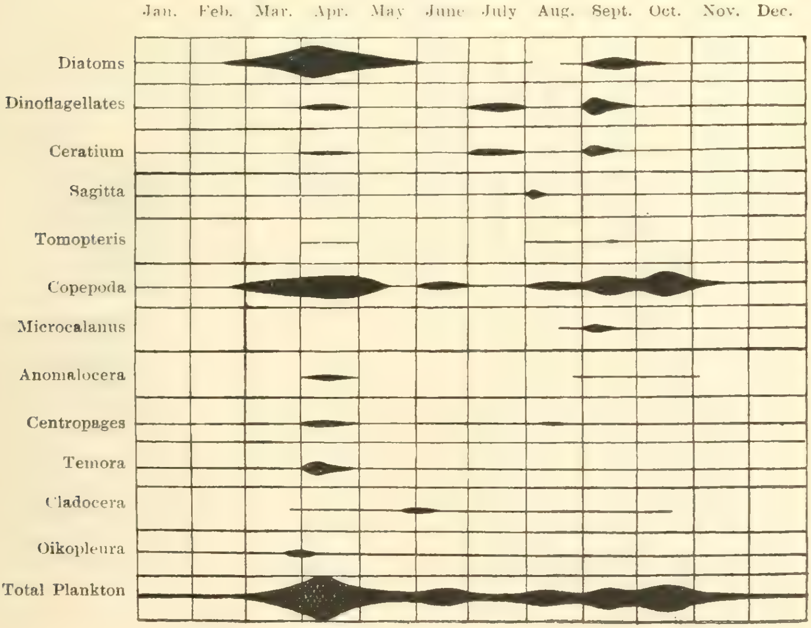
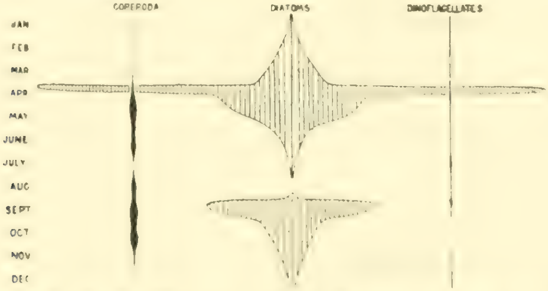


Fig. 20. Distribution throughout the year 1907—diagrammatic.

Thus, the Diatoms took on an enormous development in early spring, and reached their maximum in April, then died down during the summer, and rose again (in 1907) to a second but much less important maximum in autumn (fig. 21). It must be borne in mind, however, that the species, and to some extent the genera, that formed the autumn increase (*Chætoceros subtile* and species of *Rhizosolenia*) were quite different from those present in spring (e.g., *Chætoceros contortum* and species of *Thalassiosira*); and also that in 1908 the autumnal rise was scarcely perceptible.



PORT ERIN PLANKTON 1907 NUMERICAL PROPORTION OF SOME GROUPS

FIG. 21.

From the list of the total plankton throughout the year, reduced to the average per net per day, it is seen that the greatest bulk of plankton in the water is in April, when the total catches in the day reached an average of 51 c.c. per haul. Other lesser elevations are seen in June with 20 c.c. and August with 25 c.c. The catch in some individual hauls runs a great deal higher than these averages, the top score being the Nansen net on April 4th, with 164·5 c.c. Fig. 22, showing the average haul of plankton per month, brings out the great range and the remarkable diversity between some adjacent months. The spring maximum in the amount of the plankton is clearly due to a great and sudden increase in the amount of Diatoms present (see fig. 21). The other rises seen later in the year, as in June, August, and to a slighter extent in October, are less marked, and are less clearly due to one cause.

The hauls taken on an off-shore station, on April 5th, show the condition of affairs during the spring maximum of the Diatoms, when 14 millions of one species, *Chætoceros contortum*, were present in one haul of the Nansen net. The total number of Diatoms in that haul was nearly 17 millions, including two millions of *Thalassiosira nordenskioldii*. Comparatively few Copepoda and other organisms were present. The two surface gatherings of this date were moderately alike, the same organisms were present in both, although one net had, in some cases, about twice as many as the other; but still

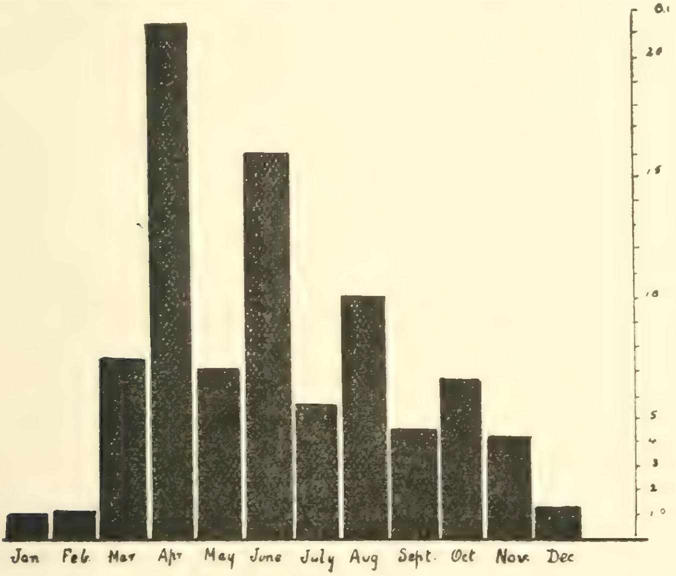


FIG. 22. Diagram showing average haul of Plankton per month in 1907.

the hauls were of the same general type and the quantities were, in most cases, not very different, showing that one can get a good general idea of the fauna by such hauls, but that one cannot depend upon their being minutely representative. They may show something like double, or, on the other hand, perhaps only one-half the quantity of organisms obtained in neighbouring hauls.

For comparison with such gatherings, we may examine the similar series taken late in August from about the same locality. On August 21st there are practically no Diatoms present, only a very few individuals of *Biddulphia mobiliensis*. On the other hand, the Copepoda are much more abundant than they were in April; for example, take *Oithona similis*, of which only tens, amounting at most to a few hundreds, were present in April, while thousands (reaching eleven thousand in the weighted net) were in the August haul. Other interesting differences can be noticed on comparing the two lists (given in the Sea-Fisheries Report in full) in detail.

The Copepoda have two maxima in 1907, the first in April and the second in September and October. The records start in January, with about 2,000 per haul, and keep below that level throughout February and most of March. During April they rapidly mount up with a series of successively higher records, with falls between such as April 2nd, 4,500; April 13th, 10,755; April 16th, 11,600; till the climax is reached on April 27th, with 29,825. During May the numbers are low, 1,045 to 6,505; in June they rise somewhat, 13,610 on the 11th and 15,150 on the 27th, falling again in July to numbers between 2,895 and 7,930. August shows a series of rises with falls between, the tops being 18,200 on the 10th, 19,400 on the 14th, 11,700 on the 15th, 16,915 on the

24th, and 10,970 on the 29th. September begins at a low level, reaches 11,942 on the 4th, and, with falls between 27,177 on the 12th, 13,440 and 27,312 on the 20th, followed by 10,582 on 21st, 18,450 on 23rd, 11,850 on 24th, and 12,110 on 30th. October is also high, with 16,973 on the 9th, 27,790 on 14th, and 24,480 on 24th. November shows one high figure, 10,937 on the 8th; while December ranges from 1,724 to 2,755; the year's record ending very much at the same level where it commenced in January. The range in number of the Copepoda per net, 30 to 29,800, is considerable compared with that of some groups, but does not equal that of the Diatoms.

The monthly averages of the Copepoda during this year (1907) are as follows:—

Jan.	1,816	July	5,462
Feb.	793	Aug.	5,496
Mar.	1,379	Sept.	6,514
Apr.	5,858	Oct.	17,572
May	3,415	Nov.	6,923
June	12,138	Dec.	2,289

The highest averages here (June and October) do not quite coincide with the maxima (April and September-October) as stated above where the days were taken singly. The explanation is, of course, that although April contains a maximum far above that of June, it also contains in the earlier part of the month many low records that pull down the average when the month is treated as a whole. The maxima in high average bulk of catch extending over the month, but not in exceptional catches, are seen from this list to be in June and October, and especially in the latter.

If we look now for the largest individual hauls of a single species of Copepod we find that they occur in April, August, and September. The following are some of the more important of these:

April	9—Pseudocalanus elongatus	16,000
	9—Temora longicornis	19,000
	23—Calanus helgolandicus	13,480
	24—Acartia clausi	28,000
Aug.	13—Oithona similis	14,000
	17— ,, ,,	25,000
	24—Acartia clausi	29,000
	27— ,, ,,	24,700
	29—Pseudocalanus elongatus	23,000
Sept.	4—Acartia clausi	23,600
	4—Pseudocalanus elongatus	36,000
	12— ,, ,,	33,600
	18— ,, ,,	25,000
	20—Oithona similis	29,270

These also bear out the idea of maxima in April and in autumn, the latter being the more important one: in both cases they follow the phytoplankton. As a rule, a haul rich in Copepoda has few Diatoms, and *vice versâ*, but the Copepoda do not, like the Diatoms, present great maxima and marked depressions. Even when both groups are present in the plankton we frequently find that they are in different zones: for example, in some April hauls in 1907 the Diatoms were markedly on the surface and the Copepoda below, while later in the year these positions were reversed.

The distribution of particular Copepoda (*Calanus*, *Anomalocera*, *Microcalanus*, *Pseudocalanus*, *Centropages*, *Temora*) have been followed separately, and some of these form interesting studies. *Calanus*, *Pseudocalanus*, *Centropages*, and *Temora* are present throughout the year: *Anomalocera* appears in our district in spring: *Microcalanus* in late autumn.

The Diatom fauna made its appearance again in September, 1907 (fig. 21). The two surface nets on September 12th show very large numbers of Diatoms, extending up to 13 millions and 16 millions in single hauls in the case of *Rhizosolenia semispina*—in fact, this highest peak in the September maximum of Diatoms is mainly composed of this one species of *Rhizosolenia*, whereas in the spring maximum the bulk of the catch is made up of *Chætoceros contortum* and *Thalassiosira nordenskioldii*, species that are rare or altogether absent in September gatherings. The genus *Thalassiosira* is mainly a spring form, rarely present after May, and is not represented in autumn in this year's results.

When a comparison is made between the three similar open tow-nets which were worked together for fifteen minutes at a time—two at or close to the surface, and the other weighted so that it was lowered to a depth of about ten fathoms, and gradually rose, as the boat went slowly ahead, to a depth of a foot or two below the surface—it is almost invariably found that the weighted net, with its wider range through the deeper layers of water, gave a larger, sometimes a much larger, quantity of organisms. The only exceptions to this rule are on some occasions in April, when the sea was full of Diatoms and the surface nets gave very large hauls, equal to, or even exceeding, the deeper ones. But even during the Diatom maximum in April some days showed more in the weighted than in the surface nets. For example, on April 10th, at alongshore Station III, the surface gave 11·5 and the net at one fathom 19·5 c.c., and the total Diatoms were 27,000 in the former and 188,000 in the latter.

In some cases, as I showed last year, the two similar surface-nets worked together gave dissimilar results. Even when the results are very much alike quantitatively, they may be very different qualitatively, and it is by no means always the two hauls that are most alike in bulk that agree best in the kind and number of organisms. It will probably be agreed that it is unlikely that, with the large, varied and irregularly scattered population that we find the sea to contain, two nets should often catch the same quantities of the same sets of organisms. Consequently, a result like that obtained on April 22nd, where the two nets caught precisely the same amounts and where the lists of organisms constituting the hauls are almost exactly alike both in kinds and numbers, is interesting.

On considering the Diatom list, some other points come out:—The average number of Diatoms per catch often varies considerably from day to day. Thus on April 5th the average of all catches of that day was 3,533,800, while on April 6th it fell to 348,750; on April 24th it was 191,873, while on April 25th it was only 663.

But these numbers scarcely give an adequate idea of the quantitative variation among individual catches. Thus on September 10th surface-nets A and B contained 250 and 550 respectively while two days later the corresponding numbers were 13,495,500 and 16,300,500; on April 8th two hauls of the Nansen net gave respectively 198,000 and 3,739,000, and many other such cases could be quoted.

Turning now to the Diatom hauls within Port Erin Bay, a general inspection of an unsmoothed curve drawn from them shows the well-marked maximum at the end of March and earlier part of April (fig. 17). The marked increase of Diatoms, and also of Copepod Nauplii, is seen well in the following three surface hauls:

	March 26. 12 c.c.	March 27. 14·5 c.c.	March 29. 18·5 c.c.
Total Diatoms =	220,000	277,000	326,000
Biddulphia mobiliensis	46,000	50,000	58,000
Chaetoceros debile	6,000	8,000	10,000
„ decipiens	100,000	150,000	160,000
Coscinodiscus concinnus	64,000	67,000	75,000
Copepod nauplii	7,000	27,000	35,000

There was also in the bay an autumn maximum, showing a very high peak at the end of September. Omitting, however, the single catch of September 30th (which is due in the main to *Rhizosolenia semispina*), the peak is reduced to less than one-third its former height. A remarkable feature of this September hump was the sudden character of its appearance and disappearance and its short duration (six days). An inspection of the temperature curve of the year for the water of the bay shows that the sudden increase in the phytoplankton coincided with the maximum in temperature; and our weekly weather records at the Biological Station show at that same time a week of fine, calm weather with easterly breezes (S.E. and E.S.E.). I have noticed the same phenomenon in previous years, both at Port Erin and on the west coast of Scotland, which seems to indicate that if weather conditions be suitable at the end of autumn the phytoplankton may suddenly increase so as to constitute a second maximum in the year, the first being in spring; but that this possible "maximum" may be so modified in time and in amount by temperature and wind as to be unrecognisable. In 1906 it was very much more marked at Port Erin than in 1907, and lasted longer, while in 1908 it was practically absent.

The phytoplankton minimum for the bay occurs in August, no Diatoms being taken from August 9th to August 23rd (see fig. 17, above).

As an example of a sudden change in the plankton, we may compare the surface hauls taken in the bay on October 1st and 14th. The total quantities of the two gatherings were 1·5 and 11·5 respectively; on the 1st, Diatoms were relatively abundant (over 91,000); by the 14th they had disappeared. But *Sagitta* and various larvæ, and especially Copepoda, had greatly increased in number by the latter date. The adult Copepoda in all numbered only 1,045 on the 1st, while they reached 27,790 by the 14th: younger forms and Nauplii had also become much more abundant. By November, however, the Diatoms were back in quantity, and Copepoda had begun to decrease.

The Dinoflagellata rose to a maximum in April, 1907, after the Diatoms; and may have a second period of sudden increase in the autumn if weather conditions are favourable. They appear to have been more abundant in September in 1908 than in 1907, and, in fact, to have maintained relatively high numbers from April throughout the summer.

Ceratium tripos is the most abundant species of Dinoflagellate in the Irish Sea, and is present practically all the year round in considerable abundance (up to 7,753 per haul) at the Isle of Man. Our 650 gatherings in 1907 showed *C. tripos* on 492 occasions.

The curve for *Ceratium tripos* agrees in general with that for the total Dinoflagellates, but differs markedly from those both of Diatoms and Copepoda. The spring maximum in the Dinoflagellates is later than that of the Diatoms, but precedes that of the Copepoda. Then, again, the September hump of the Dinoflagellates is earlier than that of the Diatoms, and much earlier than the October maximum of Copepoda. On the whole, the annual curve for the Dinoflagellates lies intermediate between those for Diatoms and Copepoda.

Sagitta is present throughout the year; it is most abundant in August, and the minimum occurs in winter (January to March). As showing the difference produced by a larger net of wider mesh, we find that during April, when the hauls with the ordinary tow-nets were giving units and tens, those taken at the same time with the shear-net ran into hundreds, as follows: 360, 123, 286, 310, 200, 200, 400, 400, 300, 800. The fact, however, that the weighted tow-net, not invariably, but usually, took a much larger number than the similar surface nets shows that *Sagitta* is usually more abundant in a zone of water below the surface, extending down to ten fathoms,

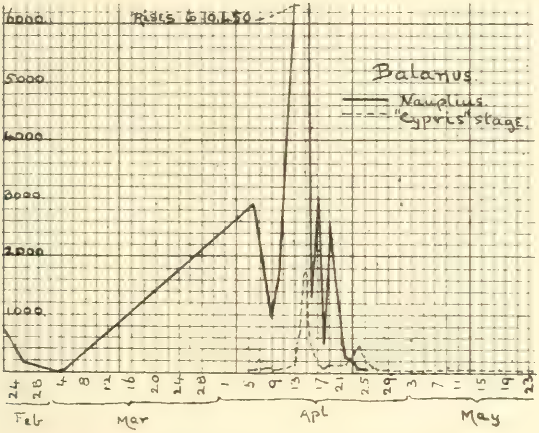


FIG. 23. Curve for larval *Balanus* in 1907.

and that consequently the much greater numbers obtained by the shear-net may be due not wholly to the size of the net and mesh but in part to the depth at which it was worked.

The Nauplius and Cypris stages of *Balanus* form an interesting study (fig. 23). The adult Barnacles are present in enormous abundance on the rocks of Bradda Head, and they reproduce in winter, at the beginning of the year. The newly-emitted young are sometimes so abundant as to make the water in the shore pools appear muddy. The Nauplii first appeared in 1907 in the bay gatherings on February 22nd (in 1908 on February 13th), and increased with ups and downs to their maximum on April 15th, and then decreased until their disappearance on April 26th. None were taken at any other time of the year. The "Cypris" stage follows on after the Nauplius. It was first taken in the bay on April 6th, rose to its maximum on the same day with the Nauplii, and was last caught on May 24th. Throughout, the "Cypris" curve keeps below that of the Nauplius, the maxima being 1,740 and 10,500 respectively. Probably the difference between the two curves represents the death-rate of the Balani during the Nauplius stage. The curve for 1908 seems to be much the same.

The two large Copepoda *Calanus helgolandicus*, Claus, and *Anomalocera pattersoni*, Temp., are both regarded as "oceanic" species, and are both present in fair abundance in the Irish Sea. They are two of the most conspicuous objects in our plankton gatherings, and can readily be picked out with the eye and counted.

Calanus was present in our gatherings in 1907 during every month of the year from January 8th to December 30th. It was represented on nearly every occasion when hauls were taken, and in some cases when absent from one net it was taken in another gathering made on the same day, showing that the apparent absence was due either to irregular distribution or to some imperfection in the sampling of the sea. When, then, we find that a species like this is not recorded from a particular haul at a time of year when gatherings are being taken once a week only, one is inclined to suspect, from the appearance of the records at other times when the observations were more frequent, that if another haul had been taken that day or on an adjoining day the missing species would have been represented. Negative evidence must always be received with some caution.

Anomalocera, on the other hand, first appears in our records on March 29th, and then only in the form of metanauplii (100, 170, and 30 in surface hauls off the Calf Island). It continues to be represented, in small numbers, by both adults and young, throughout August and September, and finally on November 8th.

The distribution of *Microcalanus pusillus*, G. O. Sars, throughout the year is interesting. It appears for the first time in our records late in August, and remains fairly constantly present, but never very abundant, throughout the autumn until January, when it disappears. During the first few weeks it is only in the off-shore hauls, appearing first out in mid-channel on August 24th in the Hensen and Nansen nets that were let down to 60 fathoms and hauled up vertically. As specimens were present in all the nets that were closed when they had been pulled up to 45 fathoms, and were not present in the surface and other nets used above this level, it is evident that this Copepod was on its first appearance only in the deep water in mid-channel. It was encountered next on August 26th, in the weighted net hauled at 10 fathoms, on the inner edge of the Train Bank, some eight miles off land. On August 31st it made its appearance at Station I, in the Hensen and Nansen nets hauled up from 24 fathoms, and in the weighted net from 10 fathoms—the latter having 350 specimens. It was also present on September 2nd and 3rd, under the same circumstances. On September 4th we again found it in mid-channel in the vertical nets which had been down to 60 fathoms; it was still not present in the surface nets nor in the in-shore waters. On September 6th *Microcalanus* appeared for the first time in-shore, at Station IV, off the Calf Island, but only in the Hensen and Nansen nets which had been closed at 8 and 15 fathoms respectively; it was not present in the surface hauls taken at the same time. It was next met with on September 11th, at Station V, south of Calf Sound, inside the Wart Bank, when 100 specimens were taken in each of the two surface nets, 150 in the weighted net at 10 fathoms, and 5, 5, 5, 3 in the four vertical nets (two Hensen and two Nansen) hauled from 20 up to 10 fathoms. It had evidently become distributed by this time all through the water around the Calf Island. The following day the species was present in nearly all the numerous nets worked at various depths down to 60 fathoms in mid-channel; and it then reached its climax in numbers, 2,000 in the net at 10 fathoms and 2,500 in an open tow-net attached to the shear-net at 20 fathoms. Finally, on September 21st, *Microcalanus* turned up for the first time in the surface gatherings taken across Port Erin Bay. It was present in these bay gatherings on October 1st (35) and 24th (100), November 8th (100), December 20th (80) and 23rd (50), and, finally, January 8th (50 specimens).

This record looks like the immigration of an oceanic species in summer up the deep water of the mid-channel between the Isle of Man and Ireland, and then its gradual spread in late autumn into the shallower in-shore waters and finally to the surface of the bay, where it remained throughout the winter.

Centropages hamatus (Lilljeborg) occurs in the Irish Sea all the year round. It is on our records for 1907 in every month, and is practically continuously present from January 8th to December 30th. The numbers are low at the beginning of the year, but reach 600 in one haul of the surface net by April 9th, and 1,300 on April 24th. Contrary to the usual rule, this species seems more abundant on the surface than deeper.

Temora longicornis (Müll.) occurs the whole year round from January to December, attains to high numbers in early spring, and remains fairly abundant into late autumn. It reaches close on 7,000 in one haul on April 1st, and 19,000 on April 9th: and shows 1,280 and 1,600 up to the 23rd September. *Temora longicornis* seems to be equally abundant inside the bay and in the open sea, on the surface and in the deeper waters. Sometimes the large numbers are in the surface nets, and at other times in the weighted net from below. This is one of the species that congregates in swarms, and so is occasionally caught in unusually large numbers. Of four similar hauls taken across Port Erin Bay on April 13th, the first two gave 875 and 620 and the last two 1,550 and 3,700 specimens of *Temora.* On the same date three hauls (two surface and one deeper) taken outside (Station III) gave 800, 850 and 900 specimens, which seems to indicate an even distribution, but half an hour later a couple of miles away the same two surface nets gave 2,400 and 4,750 specimens; and moreover in this last case nearly all the *Temora* in the 2,400 were young, while in the second net the 4,750 were all adults, indicating a segregation of the stages in swarms.

A set of hauls were taken at the end of August on Station V, inside the Wart Bank. One remarkable feature of this occasion was that the Hensen net hauled up from 14 fathoms contained 150 specimens of what is probably a new species of *Leptopsyllus*, while the Nansen net used at the same time, and at the same depth, on the other side of the ship, caught twice as much material but not a single specimen of the new Copepod. The surface nets are also somewhat divergent in their results, while the deeper weighted net has caught a very much larger quantity of material, the greater part of which is clearly made up of Copepoda both young and old—about ninety-five thousand in all.

The two species of Cladocera found in our district, *Podon intermedium* and *Evadne nordmanni*, occur mainly in summer, in a wide sense, ranging from the end of March to the beginning of October. Our first record of *Podon* is six specimens on March 26th, and the last is fifty on October 9th. *Evadne* begins with ten on March 29th, reached 500 on April 9th, and ends with 50 on September 20th. Tens, twenties and thirties are common numbers in the records of both species, but sometimes the hundreds are reached. As a rule there is no great difference between surface and deeper hauls, and occasionally there is a great constancy of results, indicating an even distribution:—e.g., on April 18th at ten miles out.

At Station II.	Surface nets.		10 faths.	Shear.	
Podon intermedium ...	150	150			
Evadne nordmanni ...	100	100	150	50	50

On April 19th, in the bay, two similar surface hauls took 40 and 37 *Podon*, and 75 *Evadne* each; and at the same time, at Station II, ten miles off, the two surface nets took 40 *Podon* and 75 *Evadne* each. Other similar cases might be quoted; but on the other hand there are diverse hauls on other dates showing a very uneven distribution. The numbers during May and June are relatively high:—

Podon ...	190	80	150	100	100	150
Evadne ...	60	80	300	300	300	650

This is the highest point reached by *Evadne*, and this form is practically absent, or only occasionally present, during the latter half of August and parts of September. *Podon* reaches a climax (500) rather later, on August 15th, and soon after that drops to tens and even units, with an occasional appearance (August 31st, 200) in greater numbers. During most of September the group is but scantily represented; although neither species is ever absent for long, and occasional larger numbers occur—such as September 19th, off Calf Island, deep net, *Podon* 70 and *Evadne* 100, and September 20th, Station I, shear net, *Podon* 110 and 290, deep net 140, and, at the same time, inside the bay, 182. On September 23rd the ordinary surface net inside the bay took 550 *Podon*, and the following day 100, after which the numbers fall off rapidly.

The common species of *Oikopleura* that occurs in our district (*O. dioica*) is also a form which seems to deserve special notice. It occurs throughout the year, being present in every month, and represented in nearly every gathering. It is absent or rare in the case of the hauls taken on a few dates between August 24th and 28th, and then again on September 4th and 5th. With those exceptions, *Oikopleura* is one of the most constant of organisms at all times of the year, and, moreover, is usually present in quantities that range within narrow limits, so that it does not vary to the extent that some Copepoda and Diatoms do. In the winter months—December, January, February and March—the numbers taken are low, but from April to November inclusive quantities of a thousand or two per net are very frequently taken. The highest numbers occur in April, and they only reach 5,500 per net, so there is no marked maximum. In some cases the numbers of *Oikopleura* remain remarkably constant for several hauls, indicating a very general distribution through the water. For example, in one traverse of Port Erin Bay 2,780 were caught, and in the return traverse 2,030; then again, two adjacent hauls gave 3,840 and 3,600 respectively, and another pair of simultaneous hauls gave 2,250 each. But on the other hand, on another occasion, two successive traverses of the bay gave 5,050 and 2,480 respectively, and other examples of diverse results might be quoted from our records. But on the whole the impression received by an inspection of the forms for 1907 is that *Oikopleura* is more evenly distributed through the water than most of the other common organisms.

In regard to the horizontal distribution, a mere inspection of our results shows in some cases close resemblances between adjacent stations (such as I and II) on the same day, or between adjacent days at the same station, and in other cases just as striking differences. How far these points of similarity and of divergence are normal and are fundamental, or how far they are due to wind, sun, and other weather conditions, or to tidal or other currents will require detailed consideration and comparison with the results obtained in other years.

A further point that has been brought out in the progress of this investigation is the obvious distribution of at least some organisms in swarms. This can occasionally be seen by the eye, when, for example, shoals of large Medusæ are encountered which are so abundant for a limited area that on a calm day they may cover the surface like a tessellated pavement, and assume polygonal forms from mutual pressure. On other occasions the nets have evidently encountered swarms of Copepoda, of Cirripede Nauplii, of Crab Zoeas, of worm larvæ or of other organisms. One might expect such results in the case of neritic forms, which are merely stages in the life-history of some gregarious organism: but the occurrence is by no means confined to such, it extends to oceanic organisms on the high seas, and this sporadic distribution in swarms has not been sufficiently taken into account by some writers who have treated of the distribution of the plankton in recent years.

The Irish Sea contains a surprising number of what are sometimes regarded as "oceanic" species—not merely as occasional visitants, but as normal and continuous constituents of the plankton during a great part of the year. Amongst these may be mentioned *Chatoceros densum*, *Coscinodiscus radiatus*, *Rhizosolenia semispina*, *Ceratium tripos*, *Peridinium* sp., *Tomopteris onisciformis*, *Pleurobrachia pileus*, *Calanus helgolandicus*, *Anomalocera pattersoni*, *Acartia clausi*, *Oithona similis*, and *Oikopleura dioica*. Some of these oceanic species seem, so far as we can judge from the published records, to be more abundant and more continuously present round the Isle of Man than they are even in the western part of the English Channel.

We have evidence from our closing vertical nets that the zone of most abundant life is not on the surface but is generally a few fathoms below—say, usually, between 5 and 10 fathoms. Samples of water from 5, 10 and 20 fathoms obtained with the "Mill" water-bottle support the above statement. But this conclusion was arrived at and could be established, quite apart from the evidence of the vertical nets, from a comparison of the results obtained by the weighted and surface open horizontal tow-nets. At the time of the Diatom maximum in spring, however, our closing vertical nets showed that these Protophyta are more abundant in still deeper zones, and increase in density downwards to at least 20 fathoms.

In the cases of some groups, e.g., Cladocera and Oikopleura, the distribution is sometimes remarkably regular, the same numbers being taken simultaneously by comparable nets at localities up to ten miles apart; but on the other hand even with these same groups there may, on other dates, be very diverse hauls indicating an uneven distribution. Some species, and some groups of neritic larvæ markedly congregate in shoals, and this also adds to the unevenness of the distribution.

The horizontal distribution of the plankton is consequently liable to be very variable and irregular, and although its characteristic constitution at different times of the year may be described, and the relative abundance of the different groups discussed, it is very doubtful whether any numerical estimates can be framed which will be applicable to wide areas.

It is clear that samples taken quarterly, monthly, or even fortnightly, are quite inadequate to convey a correct idea of the constitution and changes of the plankton of a sea-area in any detail; and, consequently, conclusions ought not to be drawn from such insufficient observations. Samples, taken weekly throughout the year, and almost daily during the three most critical months, give by no means too much information, but will probably suffice to enable one to make that detailed comparison between adjacent localities and dates which are necessary for the purpose of determining the representative value of such periodic samples.

L.M.B.C. Memoirs.

Dr. Pearson's important Memoir on Cancer, the edible crab, was published last summer, and is one of the largest and most comprehensive monographs of this series, extending as it does to over 200 pages and 12 plates. The next Memoir, No. XVII., on Pecten, the scallop, by Mr. Dakin is now in type, and will be issued immediately after this report before the end of the year. The following Memoir, No. XVIII, on Eledone, by Miss A. Isgrove, is completed, and the MS. and drawings are now in my hands awaiting publication. Doris, the sea-lemon, by Sir Charles Eliot, and other Memoirs are also far advanced; and we hope to have a Memoir on our Irish Sea species of Ceratium and other Dinoflagellata from Prof. C. A. Kofoid, who did some work on our local material during his visit here last summer. This unusual amount of excellent material, which the Committee is happy to be able to issue to the scientific world, is, however, embarrassing from the point of view of expense. Lithographic plates, such as these Memoirs require, seem to become more costly, and with the growing elaboration of the subject more detailed illustration is necessary. The Committee are therefore very grateful for several special donations and grants which have enabled the Treasurer to meet the expenses of plates for several of the above-mentioned Memoirs. Further donations to provide for the illustrations of those still unpublished will be very welcome.

The following shows a list of the Memoirs already published or arranged for:—

I. Ascidia, W. A. Herdman, 60 pp., 5 Pls.
II. Cardium, J. Johnstone, 92 pp., 7 Pls.
III. Echinus, H. C. Chadwick, 36 pp., 5 Pls.
IV. Codium, R. J. H. Gibson and H. Auld, 26 pp., 3 Pls.
V. Alcyonium, S. J. Hickson, 30 pp., 3 Pls.
VI. Lepeophtheirus and Lernæa, A. Scott, 62 pp., 5 Pls.
VII. Lineus, R. C. Punnett, 40 pp., 4 Pls.
VIII. Plaice, F. J. Cole and J. Johnstone, 260 pp., 11 Pls.
IX. Chondrus, O. V. Darbishire, 50 pp., 7 Pls.
X. Patella, J. R. A. Davis and H. J. Fleure, 84 pp., 4 Pls.
XI. Arenicola, J. H. Ashworth, 126 pp., 8 Pls.
XII. Gammarus, M. Cussans, 55 pp., 4 Pls.
XIII. Anurida, A. D. Imms, 107 pp., 8 Pls.
XIV. Ligia, C. G. Hewitt, 45 pp., 4 Pls.

XV. Antedon, H. C. Chadwick, 55 pp., 7 Pls.
XVI. Cancer, J. Pearson, 217 pp., 13 Pls.
XVII. Pecten, W. J. Dakin, 120 pp., 9 Pls.
XVIII. Eledone, A. Isgrove.
Doris, Sir Charles Eliot.
Oyster, W. A. Herdman and J. T. Jenkins.
Ostracod (Cythere), Andrew Scott.
Buccinum, W. B. Randles.
Bugula, Laura R. Thornely.
Zostera, R. J. Harvey Gibson.
Himanthalia, F. J. Lewis.
Fucus, J. B. Farmer.
Cucumaria, E. Hindle.
Peridinian, C. A. Kofoid.
Sagitta, E. J. W. Harvey.
Diatoms, F. E. Weiss.
Botrylloides, W. A. Herdman.
Sabellaria, Arnold T. Watson.
Actinia, J. A. Clubb.
Halichondria and Sycon, A. Dendy.
Hydroid, E. T. Browne.

In addition to these, other Memoirs will be arranged for, on suitable types, such as *Pagurus*, *Pontobdella*, a Cestode and a Pycnogonid.

We append to this Report:—

(A) The usual Statement as to the constitution of the L.M.B.C., and the Laboratory Regulations;
(B) The Hon. Treasurer's Report, List of Subscribers, and Balance Sheet.

APPENDIX A.

THE LIVERPOOL MARINE BIOLOGY COMMITTEE (1908).

His Excellency the Right Hon. Lord Raglan, Lieut.-Governor of the Isle of Man.

The late Mr. R. D. Darbishire, F.G.S., Manchester.

Prof. R. J. Harvey Gibson, M.A., F.L.S., Liverpool.

Mr. W. J. Halls, Liverpool.

Prof. W. A. Herdman, D.Sc., F.R.S., F.L.S., Liverpool, Chairman of the L.M.B.C., and Hon. Director of the Biological Station.

Dr. W. E. Hoyle, M.A., University, Manchester.

Mr. P. M. C. Kermode, Ramsey, Isle of Man.

The late Mr. A. Leicester, Liverpool.

Sir Charles Petrie, Liverpool.

Mr. E. Thompson, Liverpool, Hon. Treasurer.

Mr. A. O. Walker, F.L.S., J.P., formerly of Chester.

Mr. Arnold T. Watson, F.L.S., Sheffield.

Curator of the Station—Mr. H. C. Chadwick, A.L.S.

Assistant—Mr. T. N. Cregeen.

CONSTITUTION OF THE L.M.B.C.

(Established March, 1885.)

I.—The Object of the L.M.B.C. is to investigate the Marine Fauna and Flora (and any related subjects such as submarine geology and the physical condition of the water) of Liverpool Bay and the neighbouring parts of the Irish Sea and, if practicable, to establish and maintain a Biological Station on some convenient part of the coast.

II.—The COMMITTEE shall consist of not more than 12 and not less than 10 members, of whom 3 shall form a quorum; and a meeting shall be called at least once a year for the purpose of arranging the Annual Report, passing the Treasurer's accounts, and transacting any other necessary business.

III.—During the year the AFFAIRS of the Committee shall be conducted by an HON. DIRECTOR, who shall be Chairman of the Committee, and an HON. TREASURER, both of whom shall be appointed at the Annual Meeting, and shall be eligible for re-election.

IV.—Any VACANCIES on the Committee, caused by death or resignation, shall be filled by the election at the Annual Meeting, of those who, by their work on the Marine Biology of the district, or by their sympathy with science, seem best fitted to help in advancing the work of the Committee.

V.—The EXPENSES of the investigations, of the publication of results, and of the maintenance of the Biological Station shall be defrayed by the Committee, who, for this purpose, shall ask for subscriptions or donations from the public, and for grants from scientific funds.

VI.—The BIOLOGICAL STATION shall be used primarily for the Exploring work of the Committee, and the SPECIMENS collected shall, so far as is necessary, be placed in the first instance at the disposal of the members of the Committee and other specialists who are reporting upon groups of organisms; work places in the Biological Station may, however, be rented by the week, month, or year to students and others, and duplicate specimens which, in the opinion of the Committee, can be spared may be sold to museums and laboratories.

LIVERPOOL MARINE BIOLOGICAL STATION

AT

PORT ERIN.

Laboratory Regulations.

I.—This Biological Station is under the control of the Liverpool Marine Biological Committee, the executive of which consists of the Hon. Director (Prof. Herdman, F.R.S.) and the Hon. Treasurer (Mr. E. Thompson).

II.—In the absence of the Director, and of all other members of the Committee, the Station is under the temporary control of the Resident Curator (Mr. H. C. Chadwick), who will keep the keys, and will decide, in the event of any difficulty, which places are to be occupied by workers, and how the tanks, boats, collecting apparatus, &c., are to be employed.

III.—The Resident Curator will be ready at all reasonable hours and within reasonable limits to give assistance to workers at the Station, and to do his best to supply them with material for their investigations.

IV.—Visitors will be admitted, on payment of a small specified charge, at fixed hours, to see the Aquarium and Museum adjoining the Station. Occasional public lectures are given in the Institution by members of the Committee.

V.—Those who are entitled to work in the Station, when there is room, and after formal application to the Director, are:—(1) Annual Subscribers of one guinea or upwards to the funds (each guinea subscribed entitling to the use of a work place for three weeks), and (2) others who are not annual subscribers, but who pay the Treasurer 10s. per week for the accommodation and privileges.

Institutions, such as Universities and Museums, may become subscribers in order that a work place may be at the disposal of their students or staff for a certain period annually; a subscription of two guineas will secure a work place for six weeks in the year, a subscription of five guineas for four months, and a subscription of £10 for the whole year.

VI.—Each worker is entitled to a work place opposite a window in the Laboratory, and may make use of the microscopes and other apparatus, and of the boats, dredges, tow-nets, &c., so far as is compatible with the claims of other workers, and with the routine work of the Station.

VII.—Each worker will be allowed to use one pint of methylated spirit per week free. Any further amount required must be paid for. All dishes, jars, bottles, tubes, and other glass may be used freely, but must not be taken away from the Laboratory. Workers desirous of making, preserving, or taking away collections of marine animals and plants, can make special arrangements with the Director or Treasurer in regard to bottles and preservatives. Although workers in the Station are free to make their own collections at Port Erin, it must be clearly understood that (as in other Biological Stations) no specimens must be taken for such purposes from the Laboratory stock, nor from the Aquarium tanks, nor from the steam-boat dredging expeditions, as these specimens are the property of the Committee. The specimens in the Laboratory stock are preserved for sale, the animals in the tanks are for the instruction of visitors to the Aquarium, and as all the expenses of steam-boat dredging expeditions are defrayed by the Committee, the specimens obtained on these occasions must be retained by the Committee (*a*) for the use of the specialists working at the Fauna of Liverpool Bay, (*b*) to replenish the tanks, and (*c*) to add to the stock of duplicate animals for sale from the Laboratory.

VIII.—Each worker at the Station is expected to lay a paper on some of his results—or at least a short report upon his work—before the Biological Society of Liverpool during the current or the following session.

IX.—All subscriptions, payments, and other communications relating to finance, should be sent to the Hon. Treasurer. Applications for permission to work at the Station, or for specimens, or any communications in regard to the scientific work should be made to Professor Herdman, F.R.S., University, Liverpool.

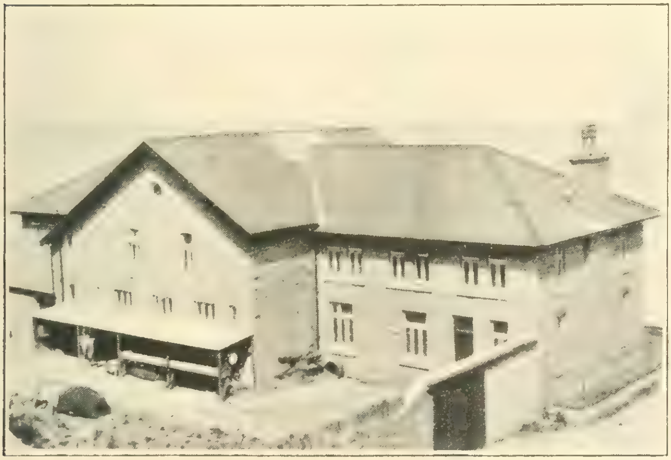


FIG. 24. The Biological Station from the cliff behind.

Appendix B.

HON. TREASURER'S STATEMENT.

In the following few pages is shown the list of Subscribers and Balance Sheet for 1908. The latter shows a balance of £18 in hand which, however, will disappear in the course of the next few weeks since the stock of bottles, chemicals, and other supplies, which is usually laid in at this time of the year, has not yet been bought. When this necessary expenditure has been made the account will probably show a small balance due to the Treasurer.

As has been mentioned earlier in this Report, several of our subscribers have died during the past year, and the Treasurer would like to point out the necessity of adding to the list of subscribers, as every year the expenses of the Port Erin Biological Station are heavier, the work done there being continually on the increase.

The L.M.B.C. Memoirs are being published in rapid succession as funds permit. During the past year Cancer (the edible crab) has been issued; Pecten (the common scallop) is now in the printers' hands, and Eledone (an Octopod Cuttle-fish) will be ready early next year.

These Memoirs are illustrated with beautifully-reproduced plates, which are necessarily expensive, and, as the Balance Sheet shows, there is a sum of £114 in hand (allocated by the donors to this purpose), which will have to be almost at once expended on the Memoirs now ready for publication.

The Treasurer will therefore gladly receive further donations for this purpose, or subscriptions to meet the necessary working expenses of the Biological Station at Port Erin.

Edwin Thompson,
Hon. Treasurer.

1, Croxteth Grove,
Liverpool.

SUBSCRIBERS.

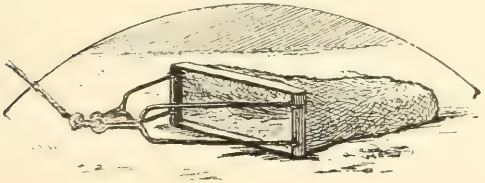
	£	s.	d.
Beaumont, W. I., Citadel Hill, Plymouth ...	1	1	0
Briscoe, F. W., Colby, Isle of Man	0	10	6
Brown, Prof. J. Campbell, University, Liverpool..	1	1	0
Browne, Edward T., B.A., 141, Uxbridge-road, Shepherd's Bush, London	1	1	0
Boyce, Sir Rubert, F.R.S., University, Liverpool	1	1	0
Brunner, Mond & Co., Northwich...	1	1	0
Brunner, Sir John, Bart., M.P., Silverlands, Chertsey	5	0	0
Brunner, J. F. L., M.P. 23, Weatherley Gardens, London, S.W.	2	2	0
Bullen, Rev. R. Ashington, Heathside-road, Woking	1	1	0
Caton, Dr., 78, Rodney-street, Liverpool	1	1	0
Clubb, J. A., Public Museums, Liverpool... ...	0	10	6
Crellin, John C., J.P., Andreas, I. of Man... ...	0	10	6
Crosfield, Harold G., Fulwood-park, Liverpool ...	1	1	0
Dale, Vice-Chancellor, University, Liverpool ...	1	0	0
Davis, Principal Ainsworth, Agricultural College, Cirencester	1	1	0
Dixon-Nuttall, F. R., J.P., F.R.M.S., Prescot ...	2	2	0
Eliot, Sir Charles, University, Sheffield	1	1	0
Gair, H. W., Smithdown-road, Wavertree ...	2	2	0
Gaskell, Holbrook, J.P., Woolton Wood	1	1	0
Halls, W. J., 35, Lord-street, Liverpool	1	1	0
Headley, F. W., Haileybury College, Hertford ...	1	1	0
Herdman, Prof., F.R.S., University, Liverpool ...	2	2	0
Hewitt, David B., J.P., Northwich	1	1	0
Hickson, Prof., F.R.S., University, Manchester ...	1	1	0
Holland, Walter, Carnatic Hall, Mossley Hill ...	2	2	0
Holt, Alfred, Crofton, Aigburth	2	2	0
Holt, Alfred, Junr., Crofton, Aigburth	1	0	0
Forward	£36	18	6

	£	s.	d.
Forward... ...	36	18	6
Holt, Mrs., Sudley, Mossley Hill	2	2	0
Holt, P. H., Croxteth-gate, Sefton-park	1	1	0
Holt, the late R. D., 54, Ullet-road, Liverpool ...	2	0	0
Hoyle, Dr. W. E., Museum, Owens College ...	1	1	0
Isle of Man Natural History Society	2	2	0
Jarmay, Gustav, Hartford, Cheshire	1	1	0
Jones, the late Charles W., J.P., Allerton Beeches	1	0	0
Lever, W. H., M.P., Thornton Hough, Cheshire	1	1	0
Lewis, Dr. W. B., W. Riding Asylum, Wakefield...	1	0	0
Manchester Microscopical Society...	1	1	0
Meade-King, R. R., 4, Oldhall-street	0	10	0
Mond, R., Sevenoaks, Kent...	5	0	0
Monks, F. W., Warrington...	2	2	0
Muspratt, E. K., Seaforth Hall	5	0	0
Narramore, W., Cambridge Avenue, Great Crosby	1	1	0
O'Connell, Dr. J. H., Dunloe, Heathfield-road, Liverpool	1	1	0
Petrie, Sir Charles, Devonshire-road	1	1	0
Quayle, Alfred, 7, Scarisbrick New-road, Southport	1	1	0
Rae, Edward, Courthill, Birkenhead	1	1	0
Rathbone, Mrs. Theo., Backwood, Neston... ...	1	1	0
Rathbone, Miss May, Northumberland-street, London	1	1	0
Rathbone, Mrs., Green Bank, Allerton	2	0	0
Roberts, Mrs. Isaac, Thomery, S. et M., France ...	1	1	0
Robinson, Miss M. E., Holmfield, Aigburth, L'pool	1	0	0
Simpson, J. Hope, Ivy lodge, Aigburth	0	10	6
Smith, A. T., 43, Castle-street	1	1	0
Sorby, the late Dr. H. C., F.R.S., Broomfield, Sheffield	1	1	0
Tate, Sir W. H., Woolton, Liverpool	2	2	0
Thompson & Capper, 4, Lord-street, Liverpool ...	1	1	0
Forward	£80	3	0

	£	s.	d.
Forward	80	3	0
Thornely, Miss, Nunclose, Grassendale	0	10	0
Thornely, Miss L. R., Nunclose, Grassendale ...	2	2	0
Timmis, T. Sutton, Cleveley, Allerton	2	2	0
Toll, J. M., 49, Newsham-drive, Liverpool ...	1	1	0
Walker, Alfred O., Ulcombe Place, Maidstone ...	3	3	0
Watson, A. T., Tapton-crescent, Sheffield... ...	1	1	0
Whitley, E., Clovelly, Sefton-park, Liverpool ...	2	2	0
Weiss, Prof. F. E., Owens College, Manchester ...	1	1	0
Wiglesworth, Dr., Rainhill...	1	1	0
Wragg, Sir W., D.C.L., Port St. Mary, Isle of Man	1	1	0
Yates, Harry, 75, Shudehill, Manchester... ...	1	1	0
	£96	8	0

SUBSCRIPTIONS FOR THE HIRE OF "WORK-TABLES."

Victoria University, Manchester	£10	0	0
University, Liverpool	10	0	0
University, Birmingham	10	0	0
	£30	0	0



The Naturalist's Dredge.

THE LIVERPOOL MARINE BIOLOGY COMMITTEE.

Dr. IN ACCOUNT WITH EDWIN THOMPSON, HON. TREASURER. **Cr.**

1908.	£	s.	d.
To Balance due Treasurer, December, 1907	0	16	0
„ Printing and Stationery	1	8	4
„ Balance of Printing "Cancer" Memoir	24	9	3
„ Balance of Plates for "Cancer" Memoir	5	15	0
„ Printing Reports	32	12	5
„ Sundries	9	0	11
„ Books and Apparatus for Biological Station	16	6	5
„ Boat Hire	3	6	0
„ Postage and Carriage	6	1	3
„ Share of Salary of Curator	75	0	0
„ „ „ Assistant	27	6	0
„ Memoir Fund—Amount transferred	50	0	0
„ Balance in hand	18	5	0
	£270	6	7

EDWIN THOMPSON,
HON. TREASURER.

LIVERPOOL, *December 11th, 1908.*

1908.	£	s.	d.
By Subscriptions and Donations received	109	11	6
Donation from the late Mr. C. W. Jones	10	0	0
„ Amount received from Universities for hire of "Work Tables"	30	0	0
„ Dividend, British Workman's Public House Co., Ltd., Shares	4	19	0
„ Sale of Natural History Specimens	3	9	1
„ Interest on British Association (1896) Fund	38	0	0
„ Bank Interest	1	18	4
„ Laboratory and Class Fees	5	5	0
„ Sale of "Guides to Aquarium"	10	9	6
„ Sale of Bottles	0	13	5
„ Admissions to Aquarium (Share of)	32	8	10
„ Sale of Memoirs	23	11	11
	£270	6	7

Endowment Invested Fund:-

	£	s.	d.
British Workman's Public House Co.'s Shares	£173	1	0
Memoir Fund—Balance in Bank	£114	6	0

Audited and found correct,

COOK & LEATHER,
Chartered Accountants.

NOTE ON *NEOPLEUSTES BICUSPIS* (KROYER AND *N. MONOCUSPIS* (SARS).

By ALFRED O. WALKER, F.L.S.

In "Nature," vol. 78, p. 36, allusion is made to an article by Dr. D. S. Jordan in the "American Naturalist" in the following words:—"Starting with the axiom that in any region the nearest representative of a given species is to be found, not in the same region or in a remote region, but in a neighbouring district separated from the first by a barrier of some kind or other, the author points out that this *law* rests," &c.

In Chambers's Dictionary an axiom is defined as "a self-evident truth; a universally received principle in an art or science." It is pretty generally understood what a Natural Law means.

I do not know how far the above principle is accepted as an axiom or law, but the following fact is very difficult to reconcile with it. In April, 1907, I spent a couple of hours dredging in the hole near the Britannia Bridge in the Menai Straits called Pwll Fanog, in the hope of procuring specimens of *Nannonyx spinimanus*, A. O. Walker, which is only known from four specimens taken there by me in April or May, 1894. In this I was unsuccessful, but among other species I took the following:—

*1. *Neopleustes* (*Paramphithoe*) *bicuspis* (Kröyer), 13 specimens, ♂, ♀, and young.

*2. *N. monocuspis* (Sars), 16 specimens, ♂, ♀, and young.

*3. *N. assimilis* (Sars), about 50 specimens, ♂, ♀ with ova, and many young.

The specimens of 1 ranged in size from 6·5 mm. to 12 mm.
„ 2 „ 3·5 „ 9 „
„ 2 „ 2·5 „ 5·5 „

None of the females of 1 and 2 were ovigerous; of 3, four or five were.

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* G. O. Sars, *Crust. of Norway*, "Amphipoda," pp. 349-52.

In the Amphipoda Gammaridea of "Das Tierreich" the above species are placed together, with the exception of an Arctic form, *N. brevicornis* (Sars), which is placed between *N. monocuspis* and *N. assimilis*. If, therefore, we are to consider them as three distinct species, what becomes of the "axiom" or "law"? For it can hardly be pretended that there is any such "barrier" in a hole half a mile long by 300 yards wide as would suffice to separate two species! But as regards *N. monocuspis*, I ventured in the "Revision of the Amphipoda of the L.M.B.C. District"[*] to express my opinion that it was only the immature form of *N. bicuspis*—an opinion since strengthened by the discovery of an Antarctic species, *Oradarea longimana*, A.O.W.,[†] in which a precisely similar difference between old and young individuals (viz., the absence of the postero-dorsal tooth on the second pleon segment in the young) exists. But even if my view be accepted, there still remains the cohabitation of two certainly distinct but nearly allied species to be got over by the supporters of the above "law"!

On the other hand, I entirely agree with Dr. Herdman's view[‡] that species of the same genus among marine animals are rarely found associated, and I regard the above instance as exceptional, though I took the same three (or two) species together in the same place in April, 1894.

Note.—Since the above was written it has occurred to me that I have dredged *Corophium crassicorne*, Bray, and *C. bonelli*, M. Edw., in the same hole off the Little Orme, though not at the same time—the former having been taken in October and the latter in August. This is an important difference, as it is quite possible that the two species may never be together, many Amphipods being known to be migratory. -A. O. W.

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[*] *Trans. Liverpool Biol. Soc.*, Vol. IX, 1895, p. 303.

[†] *Journ. Linn. Soc. Zool.*, Vol. XXIX, p. 56.

[‡] *Trans. Liverpool Biol. Soc.*, Vol. X, 1896, p. 56.

REPORT on the INVESTIGATIONS carried on during 1908 in connection with the LANCASHIRE SEA-FISHERIES LABORATORY at the University of Liverpool, and the SEA-FISH HATCHERY at Piel, near Barrow.

Drawn up by Professor W. A. HERDMAN, F.R.S., Honorary Director of the Scientific Work: assisted by Mr. ANDREW SCOTT, A.L.S., Resident Fisheries Assistant at Piel; and Mr. JAMES JOHNSTONE, B.Sc., Fisheries Assistant at the Liverpool Laboratory.

(With plates and text figures.)

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INTRODUCTION AND GENERAL ACCOUNT OF THE WORK.

One of the most important events of the past year in connection with the Sea Fisheries investigations in this country has been the Enquiry and the subsequent Report of the Treasury Committee which sat under the Chairmanship of Mr. H. J. Tennant, M.P. This Committee certainly considered the organisation, the equipment, and the work of the Lancashire and Western Sea Fisheries district very thoroughly. They not only heard evidence from the Chairman and other members of the Committee, as well as from the Superintendent and the Honorary Director of the scientific work, at their sittings in London; but they also visited our district, inspected very fully the Laboratory at Liverpool, where they held an informal meeting and took additional evidence, and also, on the invitation of the Chairman of our Committee, had a trip on board the new steamer, "James Fletcher." All the scientific members of Mr. Tennant's Committee, as well as others, were present on these visits to the laboratory and steamer, and took an expert interest in the details of the work. I think there can be little doubt but that our arrangements were thoroughly approved of, and that it was generally felt that the local effort which had been so great and well sustained in the past was worthy of recognition and support from the Government in the future.

Whether the report of Mr. Tennant's Committee will lead to action on the part of the Government which will give us on the West Coast the amount of support to which we consider we are entitled is very doubtful, but as public money supplied by the Treasury is being expended on similar investigations on the Eastern and on the Southern Coasts of England, it must surely be clear to all who make an impartial examination of the subject that some measure of support at least should be given to our investigations on the West Coast. It is possible that before this Report is actually published the matter may be decided; but I should like to say that it has never been brought more forcibly before me than in the preparation of this report that almost every department of our work and every investigation we undertake requires further financial support, and ought to be strengthened by the work of additional hands. We require a naturalist to take charge of the observational work on the new steamer, and we require a chemical assistant to carry on the volunteer investigations so kindly conducted for us in the past by Dr. Bassett. These are two of our greatest but by no means our only needs.

The publication of the Report of the Government Committee has been followed more recently by the Blue Book (Cd. 4304) containing the evidence laid before the Committee. It is doubtful whether any useful purpose can be served now by discussing the Report and the volume of Evidence in detail. It is a question whether anyone can foresee yet what the ultimate result of the Committee's Report will be. There is, first of all, the natural doubt as to whether the Government will take any immediate action upon the Report; and secondly whether, even if they do re-organise fishery affairs, they will adopt the recommendations of the Committee as they stand or will modify the scheme proposed. Some modification would probably fit in best with the views of the Local Sea Fisheries Committees. Then there is the further question as to what effect the scheme outlined in the Report, or some modification of it, will have upon the rational exploitation of our National Fisheries.

The Committee propose that a Central Fisheries Council, representative of the three kingdoms, should be established for scientific and statistical purposes. The Committee were divided as to whether General Fisheries Administration should be added to the functions of the Council. The members of the Council, it is proposed, should be representative of the three National Departments of Fisheries, and of the Treasury, under the directorship of a Chairman nominated by the Treasury. In fact, the whole complexion of the proposed Council is official; and England, with its organised Sea Fisheries Committees round the coast, is treated exactly like

Scotland and Ireland, where no such Local Committees exist.

It is considered that the Central Council will regulate general investigations of a National and International character, leaving to the English, Scottish and Irish Government Departments the control over investigations of a more local character. The part that the scientific and statistical investigations now carried on by some of the Local Committees will play in such a scheme of work is not obvious. It is evident that the success, in both its scientific and its economic aspects, of the organisation proposed will depend very largely upon the precise modifications of these recommendations which may be adopted, the wisdom and moderation with which the details are planned and carried out, and finally upon the character of the men nominated as members of the Central Council.

The evidence of the witnesses, and some appendices, fill a large volume; and although many debatable points of considerable interest are raised which might give rise to lines of work and discussion on future occasions, it is unnecessary to refer to them now. It may be permitted, however, to add that, judging from their statements, some of the fisheries investigators from other parts of the country are evidently very imperfectly acquainted with the size and nature of the steamer, and the other facilities for both scientific and economic fisheries investigations, now available in the Lancashire and Western District. It is partly to give such information to our colleagues on other parts of the coast, as well as to put our conditions of work on permanent record, in regard to at least one side of our scientific equipment, that we supply in this report a description of the Lancashire and Western Sea Fisheries steamer "James Fletcher," drawn up by Captain Wignall and Mr. Johnstone. In addition, the scientific equipment on the S.Y. "Ladybird," at Port Erin, is available for use in our scheme of investigations.

In considering the effective laboratory power of the district, it must be remembered that we have the accommodation, apparatus and staff of three distinct institutions at our service—the Liverpool University laboratory, the Piel sea-fisheries hatchery and the Port Erin Biological Station. These have all been provided locally, and are now available for public service; but it is not too much to say that at each of these institutions work is impeded and delayed, or has even to be left undone, from want of the necessary funds.

WORK AT PIEL.

The work at the Piel Laboratory and Hatchery has been carried on on the usual lines during the past year. Mr. Scott's articles dealing with this work show that he has hatched and turned out into the sea over 13 millions of young flat fish—which is as many as the tanks, and other apparatus at his disposal, are capable of dealing with.

The fishermen's classes were as successful as usual, and the interest on the part of the fishermen shows no signs of abating. An addition will be made to the subject matter of the fourth class during the present season in the interests of those men who require some instruction in Navigation. For further details on these points I must refer to Mr. Scott's Reports printed below.

A good deal of Mr. Scott's time during the past year has been occupied in working at the details of the plankton collections made by myself and others from the yacht in the seas to the South and West of the Isle of

Man, and this work is incorporated in our joint paper on "Intensive Study of the Plankton" Part II of which will be found further on in this report.

WORK AT THE LIVERPOOL LABORATORY.

Mr. Johnstone's work scarcely requires to have special attention drawn to it, as it is in the main a continuation of his previous work on fish parasites, on marked fish, and on various bacteriological investigations. I may say, however, that there are two unusually important matters which have engaged our special attention in the Liverpool laboratory during the past few months, namely:—(1) the results of the hydrographic cruises, which lead us to the conclusion that some modification of the lines of observing stations will give increased knowledge in the future; and (2) the urgent question of sewage pollution of the shellfish beds, and especially of the mussels at Conway. Both these subjects are dealt with fully in the articles that follow—by Dr. Bassett on the hydrographic work and by Mr. Johnstone on the bacteriological investigations. It is eminently desirable, in the interests both of the local fishing industry and of the general public health, that the experiments we have recently made in re-laying polluted mussels on the Conway shore be followed by the construction of a model cleansing pond somewhat on the plan of those known as basins of "dégorgement" in connection with oyster culture on the coasts of France.

From another of Mr. Johnstone's Reports, given below, it will be seen that he has been continuing his important experiments in the marking of fish, with the view of getting information as to migrations and rate of growth: and, as an extension of the same subject, he is now carrying out further work bearing upon the statistical investigation of the local Plaice fisheries by measuring and recording large numbers of the fish caught on our steamer and the sailing cutters. The importance of this information, bearing upon the working of the bye-laws in our district, scarcely requires to be pointed out. It is only by such statistics that we can hope to ascertain whether the change in the trawling restrictions is having any recognisable effect on the size of the fish caught in our area.

Mr. Johnstone's article on the diseased conditions of fishes that have been sent to us for report from the Board of Agriculture and Fisheries, and elsewhere, is a useful contribution to a large subject, including questions of human food, but needs no further comment now.

Dr. H. Bassett has very kindly continued his investigation of our samples of sea-water collected on the hydrographic cruises, and has furnished us with a valuable report which will be found below. On the whole, Dr. Bassett finds that this year's work supports conclusions he drew in last year's report, but he now shows, further, that our observations demonstrate that a narrow tongue of so-called "Gulf Stream" water runs up the centre of the Irish Sea to our district, and this invasion appears to have been rather stronger in 1908 than in the previous year. Mr. Johnstone adds another hydrographic paper dealing with the recorded temperatures in the Irish Sea in their relations to the probable movements of the water and the migrations of fishes.

In regard to further work, still in progress, I may add that:—The hydrographic investigations are being actively carried on as usual, with some recent improvements, and it is very desirable, if it could be managed, that these investigations should be made even more extensive in the future.

The difficult questions in connection with the condition of the shell-fish beds up and down the coast, and their possible pollution by sewage, are still before us and pressing for solution. In addition to the work of our own Scientific Assistants, the Local Government Board and the Fishmongers Company are both independently collecting information in regard to the existing state of affairs. It is very desirable that a careful survey of the beds in relation to sewer outfalls, and a bacteriological examination of adequate samples, as well as an extension where necessary of the series of experiments we have been making to test the efficacy of transplanting polluted shell-fish to purer water, should be made without further delay.

I have myself been engaged almost continuously throughout the Easter and Summer Vacations in taking, from the yacht, periodic plankton samples, along with specimens of water and sea temperatures, both surface and deeper, in the central part of the Irish Sea around the Isle of Man—for the purpose of studying the distribution of the plankton organisms, the comparative efficiency of different plankton nets, and the representative value of the samples taken by such methods. A full account of this work, in continuation of last year's observations, is given below by Mr. Scott and myself.

Finally, I append to the report a Memoir, by my former student Mr. W. J. Dakin, on the structure, mode of life and economic importance of "Pecten," the common edible scallop, or "clam" as it is called in the Scottish fisheries—an animal well worthy of further attention and cultivation, both as a wholesome food and as an attractive bait. The cost of producing the plates which illustrate this Memoir has been met by a grant of £20 from the University of Liverpool.

W. A. HERDMAN.

FISHERIES LABORATORY,
UNIVERSITY OF LIVERPOOL,
January 31*st*, 1909.

SEA-FISH HATCHING AT PIEL.

By Andrew Scott.

The fish hatching work carried out in the spring of 1908 produced very similar results to those of the past two years. The adult plaice were obtained by the trawl net in the closed area of Luce Bay. We have to thank the Fishery Board for Scotland for granting us permission to fish in the closed portion of this protected ground. The flounders were caught in the vicinity of Piel by the police cutter stationed in the Northern division of the Lancashire district.

The fish commenced to spawn on March 5th, and the first fertilised eggs were obtained four days later. The spawning period lasted for practically two months. During that time one million four hundred and fifty thousand plaice eggs were collected, and thirteen million five hundred thousand flounder eggs. The eggs were incubated in the Dannevig hatching apparatus in the usual way. The resulting fry were afterwards liberated in the sea. At the end of the spawning season all the adult fish were set free in the channel adjoining the establishment.

The following tables give the number of eggs collected, and of the fry hatched and set free on the dates specified :—

PLAICE (*Pleuronectes platessa*, Linn.).

			Eggs Collected.	Fry Set Free.			
March	9	...	25,000	22,000	...	March	31
,,	11	...	30,000	25,500	...	,,	,,
,,	13	..	50,000	44,000	...	April	8
,,	18	...	70,000	62,000	...	,,	,,
,,	21	...	70,000	62,000	...	,,	,,
,,	23	...	80,000	70,000	...	,,	16
,,	26	...	85,000	75,000	...	,,	,,
,,	28	...	90,000	79,000	...	,,	,,
,,	31	...	90,000	79,000	...	,,	21
April	2	...	95,000	84,500	...	,,	,,
,,	5	...	95,000	84,500	...	,,	30
,,	8	...	95,000	84,500	...	,,	,,
,,	11	...	90,000	79,000	...	,,	,,
,,	13	...	85,000	75,000	...	May	7
,,	15	...	80,000	70,000	...	,,	,,
,,	17	...	80,000	70,000	...	,,	,,
,,	21	...	80,000	70,000	...	,,	16
,,	25	...	70,000	62,000	...	,,	,,
,,	28	...	45,000	40,000	...	,,	20
,,	30	...	30,000	25,500	...	,,	,,
May	2	...	15,000	17,500	...	,,	,,
Total Eggs			1,450,000	1,281,000	Total Fry		

FLOUNDER (*Pleuronectes flesus*, Linn.).

		Eggs Collected.	Fry Set Free.		
March	9	150,000	133,000	March	21
,,	11	200,000	177,000	,,	30
,,	13	450,000	400,000	,,	,,
,,	18	600,000	532,000	,,	,,
,,	21	750,000	669,000	April	8
,,	23	750,000	669,000	,,	,,
,,	26	800,000	712,000	,,	,,
,,	28	850,000	757,000	,,	16
,,	31	900,000	800,000	,,	,,
April	2	900,000	800,000	,,	,,
,,	5	1,000,000	887,000	,,	,,
,,	8	900,000	800,000	,,	21
,,	11	850,000	757,000	,,	,,
,,	13	800,000	712,000	,,	30
,,	15	800,000	712,000	,,	,,
,,	17	750,000	669,000	,,	,,
,,	21	650,000	580,000	May	7
,,	25	600,000	532,000	,,	,,
,,	28	350,000	300,000	,,	16
,,	30	250,000	224,000	,,	,,
May	2	200,000	178,000	,,	20
Total Eggs		13,500,000	12,000,000	Total Fry.	

Total Number of Eggs	14,950,000
Total Number of Fry	13,281,000

CLASSES, VISITORS, &c., AT PIEL.

By Andrew Scott.

The desire for an opportunity of attending the classes shows no indication of abatement amongst the fishermen. There must still be a considerable number of men, distributed over the various fishing centres, who have not yet had the good fortune to be selected by the local representatives. No doubt their time will come. Of course, as the time passes the fishing population receives fresh recruits from the younger generation. There is, therefore, little likelihood of the demand for the studentships falling away so long as they continue to be offered. The Education Committee of the Lancashire County Council renewed the usual money grant which enabled forty-five fishermen, residing in the administrative County of Lancaster, to receive a course of instruction in Elementary Biology at Piel in 1908. The Cheshire Education Committee sent six men from Hoylake. The Blackpool Education Committee again sent three men. The Education Committee of Liverpool also allowed two studentships to be awarded. Altogether fifty-six men attended the classes held during the spring of 1908. The studentship holders were divided into four classes—two of fifteen each and two of thirteen as shown by the following lists:—

First Class, held March 2nd to 13th.—John Edmondson, Roosebeck; John Baxter, South Ulverston; B. Langstreth, Flookburgh; John Taylor, Bolton-le-Sands; Adam Woodhouse, Morecambe; Thomas Woodhouse, Morecambe; W. Baxter, Jr., Morecambe; John Whiteside, Lytham; Joseph Abram, Banks; William Johnson, Banks; R. Parr, Blackpool; Ezekial Salthouse, Blackpool; E. P. Stanhope, Blackpool.

Second Class, held March 16th to 27th.—Jack Porter, Ulverston: John Parker, Flookburgh: J. B. Dickinson, Grange-over-Sands: Charles Willacy, Morecambe; John Woodhouse, Morecambe: Martin Allan, Morecambe, John Hudson, Heysham; Thomas Evans, Fleetwood; Fred. Williams, Fleetwood; Geoffrey Wright, Fleetwood; Edward Ainsworth, Fleetwood; Alexander Houstan, Fleetwood; James Candlish, St. Anne's; John Ball (Silas) Banks; Richard Hunter, Banks.

Third Class, held March 30th to April 10th. —Joseph Parker, Flookburgh; Thomas Bell, Jr., Morecambe; Ruben Threlfall, Morecambe; Robert Butler, Glasson Dock; William Ainsworth, Knott End, Fleetwood; Henry Leadbetter Wilson, Fleetwood; John Gornall, Fleetwood; John Wright, Fleetwood; John Abram, Banks; Henry Bird, Hoylake; William Bird, Hoylake; J. L. Edwards, Hoylake; John Randles, Hoylake; Peter Roberts, Hoylake; John Taylor, Hoylake.

Fourth Class, held April 27th to May 8th.—Moses Woodhouse, South Ulverston; James Porter, Baicliff; James Shaw, Flookburgh; William Gerrard, Morecambe; William Swain, Morecambe; Robert Threlfall, Morecambe; Robert Atkinson, Knott End, Fleetwood; Fred Colley, Fleetwood; Charles Schofield, Fleetwood, William Moss, Fleetwood; Jeffrey Abram (Bettys) Banks; R. Edwards, Liverpool; W. Phillips, Liverpool.

The usual votes of thanks to the Sea-Fisheries Committee and to the Educational Committees for the facilities given to attend the classes were proposed and carried by the fishermen at each class.

One Class in Nature Study for school teachers was conducted during the months of April and May. The Class was organised by the Barrow Education Committee and was attended by teachers belonging to their schools. The course of instruction given was the same as that mentioned in the Annual Report for 1907.

Representatives from the Cumberland Sea-Fisheries Committee made an inspection of the establishment, and the work of the fishermen's classes, on May 5th. A large party, consisting of Members of the Lancashire Sea-Fisheries Committee and of the various Education Committees of the county visited the Laboratory under the leadership of the Chairman, Mr. James Fletcher, on May 6th. Short addresses were given to the fishermen who were at work in the class, by the Chairman and some of the other members of the party. The members of St. Matthew's Mutual Improvement Society, Barrow, visited the Laboratory during the Easter holiday. Mr. A. Harris and Mr. T. S. Dymond, two of H.M. Inspectors of evening schools, came to the establishment to inspect and report on the work of the classes for fishermen and school teachers. Professor C. A. Kofoid, from the University of California, spent part of a week-end in July at Piel, examining the local plankton and seeing the methods employed in carrying out this part of the work.

After the fish hatching and the fishermen's classes were over, the most of the time throughout the remainder of the year was given to the investigation of another extensive series of plankton collections taken at the south end of the Isle of Man by Professor Herdman. This work is a continuation of the research that was begun in 1906, and it is fully dealt with elsewhere in this report. An investigation into the size, age, sex, and food of the plaice caught by the fishermen in the vicinity of Piel was initiated in 1908. Samples of the plaice taken in the stake nets and by the ordinary trawl were bought from the men from time to time and examined. Some rather interesting results have cropped up, and it is proposed to go further into the matter in 1909, by examining about 200 fish each month.

REPORT ON EXPERIMENTS WITH MARKED FISHES DURING THE YEAR 1908.

By Jas. Johnstone.

Because of the pressure of other work only two experiments were made during 1908. The first was made at Piel on 7th April, when 196 plaice, caught in a stake-net in Barrow Channel, were put into the tanks at the Station and kept there for about a fortnight. They were then marked and liberated near to the Barrow Channel Bar. The second experiment was made while trawling, in Luce Bay, for mature plaice for the Piel and Port Erin Hatcheries.

I have to make the usual acknowledgments of the assistance given by the correspondents referred to in previous Reports.

General Summary.

	Place where the Fishes were Liberated.	Date.	No. Liberated.	No. Returned.
1	Barrow Channel	7 4 1908	196 plaice	52
2	Luce Bay	8 10 1908	50 ..	1
	Totals		246 ..	53
	Experiments of 1906			11
	Experiments of 1907			43
			Total ...	107

In all these experiments the mark employed by the English Section of the International Fishery Investigations has been employed. The labels lettered "E," used in experiment 1, 1908, were given to me by Mr. J. O. Borley, and must not be confused with those attached to fishes liberated in the English Channel or North Sea.

It will be seen that some of the fishes marked and liberated during 1906 and 1907 have been recaptured during 1908. Because of this overlapping of the results of several years, and also because of the few experiments made during 1908, I do not propose to discuss the results tabulated in this Report. We hope to be able to make several large experiments during 1909, and then sufficient data ought to have been accumulated to enable us to discuss these experiments as a whole, and in the light of other observations relating to the life-history of the plaice in the Irish Sea.

The information given in the Tables is as follows:—

1	2	3	4	5	6	7	8
No. of label	Size when liberated (inches)	Place of recapture	Date of recapture	Months in the Sea	Length when recaptured (inches)	Increase in length (inches)	Method of recapture

The letters under heading 8 mean:—ST, steam trawler; 1T, first class sailing trawler; 2T, second class sailing trawler; SN, stake net; TN, trammel net; and GN, gill net.

The condition of the fishes returned, their weights in grams, their ages, and their sexes and conditions as regards sexual maturity, have been recorded. But until the results of the experiments, as a whole, are discussed it is inadvisable to make analyses of these data.

I give the particulars relating to the marked fishes returned in the following tables. As in former years, several fishes have only been reported to me. Sometimes the fishes are gutted before being sent to the laboratory. In the latter cases it is unsafe to attempt to determine the weight.

PARTICULARS OF MARKED FISHES RETURNED DURING 1908.

Experiment 2, 1906. Station: Near Fleetwood, 19th February, 1906.

1	2	3	4	5	6	7	8
L757	10¼	No information.	—	—	—	—	—

Experiment 3, 1906. Station: Bahama Bank, 12th February, 1906.

1	2	3	4	5	6	7	8
L886	10¼	10 miles S.E. from Bahama Light Ship.	18 12 07	23	—	—	ST

Experiment 8, 1906. Station: Outside Walney Island, 31st February, 1906.

1	2	3	4	5	6	7	8
LL99	8½	8 miles S.E. from Bahama Light Ship.	26 3 08	24	13⅛	4⅝	ST

Experiment 12, 1906. Station: Off Llanphystyd, 14th June, 1906.

1	2	3	4	5	6	7	8
LL320	9½	Off Llanon, Cardigan Bay	7/7/08	0	11	1½	1T
LL316	9½	Off Godrosy Light, St. Ives Bay, 22 faths.	20/2/08	19	12¼	2¾	1T

Experiment 16, 1906. Station: Off Penkilau, Cardigan Bay, 12th July, 1906.

1	2	3	4	5	6	7	8
LL424	8¾	3 miles W. by N. from Barrels Light Ship, Wexford, 25 faths.	26/6/08	24	13⅜	3⅝	1T

Experiment 18, 1906. Station: Luce Bay, 3rd October, 1906.

1	2	3	4	5	6	7	8
LL499	12	7 miles N.W. from St. Bees Head.	3/3/08	17	—	—	ST
LL523	13¼	Mountain Foot, Co. Louth, Ireland.	14/1/08	15	15½	2¼	ST
LL529	13½	6 miles W.S.W. from St. Bees Head.	24/2/08	16	—	—	1T
LL531	13¼	Near Maughold Head, 7-8 fathoms.	20/1/08	15	14·4	1⅛	ST
LL534	13	Off Rhoad Point, Campbeltown.	28/4/08	18	15⅝	2⅝	—

Experiment 1, 1907. Station: Menai Straits. 6th February, 1907.

1	2	3	4	5	6	7	8
LL535	10	Constable Buoy, off Great Ormes Head, 12 faths.	6/9/08	20	14·1	4·1	1T
LL574	9	10 miles S.E. from Bahama Light Ship.	25/3/08	14	11·5	2·5	ST
LL576	10	Not known	8/08	19	13·6	3·6	—
LL588	7·5	2 miles E. ½ N. from Smalls Light.	27/9/08	20	13·8	6·3	—
LL600	8¼	Holyhead Outer Harbour.	22/4/08	15	12	3¾	TN
LL661	9	Red Wharf Bay, 15 faths.	16/12/07	11	11¾	2¾	1T

Experiment 3, 1907. Station: Nelson Buoy, 3rd July, 1907.

1	2	3	4	5	6	7	8
LL681	8¼	3 miles S. from Morecambe Bay Light Ship.	30/9/08	15	—	—	1T
LL683	10	12 miles S.E. from Bahama Light Ship.	22/12/07	6	—	—	1T
LL715	11	8 miles E.S.E. from Bahama Light Ship, 11 fathoms.	13/6/08	12	13⅛	2⅛	ST
LL740	8¾	Near Pinfold Buoy, Ribble	31/12/07	6	10·9	2·1	2T
LL759	8¾	Garston Deep, Mersey ...	16/12/07	6	11·5	2¾	2T
LL775	9·5	Loch Ryan, 5 faths.	8/12/08	17	12·1	2·6	—
LL787	8¼	2 miles W.N.W. from Jumbo Buoy, Ribble, 4½ fathoms.	12/11/08	16	13·8	4·5	2T
LL789	9·5	St. George's Bay, off Abergele, 5 fathoms.	8/12/08	17	15·5	6	1T
LL801	9	1½ miles S.E. from Bahama Light Ship.	21/12/07	6	11⅛	2⅛	ST
LL826	7¾ Brill.	Mostyn Deep, Dee	6/2/08	7	9·9	2·2	2T
LL828	11	6 miles S.W. from Morecambe Bay Light Ship.	5/9/08	15	14·2	3·2	ST

Experiment 4, 1907. Beaumaris Bay, 24th October, 1907.

1	2	3	4	5	6	7	8
LL630	10·5	Red Wharf Bay, 6 faths..	17/12/07	2	10·9	0·4	1T
LL632	8¾	Off Aberayron, Cardigan Bay, 15 fathoms.	19/5/08	7	8⅞	⅛	2T
LL635	9	Red Wharf Bay, 7 faths..	16/12/07	2	9·3	0·3	1T
LL640	9½	Red Wharf Bay, 10 faths.	16/12/07	2	10·5	1¼	1T
LL641	11¼	Carnarvon Bay, 13 faths..	4/1/08	14	11¾	½	1T
LL642	8½	Red Wharf Bay	18/11/08	13	12⅛	3⅝	1T
LL643	8¾	Red Wharf Bay, 7 faths...	16/12/07	2	9	¼	1T
LL645	9	Off Mostyn, Dee	9/1/08	2	9·2	¼	2T
LL648	8¼	Carnarvon Bay, 15 faths..	18/6/08	8	10½	2¼	1T
LL854	12¼	8 miles N.N.W. from Morecambe Bay Light Ship.	30/3/08	5	—	—	ST
LL857	10	Near Waterford, 48 faths.	15/5/08	7	11⅞	1⅞	ST
LL860	10½	St.George's Bay, Abergele	4/12/08	14	14⅞	4⅜	1T
LL875	10½	Smalls Light bearing S., 30 miles distant.	20/11/08	13	13¾	3¼	1T
LL876	12	5 miles S.E. from Caldy Island, 20 fathoms.	9/6/08	8	13¼	1¼	1T
LL879	9½	Off Ireland's Eye, 14 faths.	17/4/08	6	11¾	2¼	1T
LL881	9¾	Off Great Ormes Head, 13 fathoms.	20/10/08	12	13¼	3½	1T
LL883	10	Red Wharf Bay, 8 faths.	16/12/07	2	10⅛	⅛	1T
LL885	8½	Red Wharf Bay, 7 faths.	13/12/07	2	8½	0	1T
LL895	10¾	Red Wharf Bay	18/11/08	13	11½	¾	1T
LL907	10	Red Wharf Bay, 7 faths.	15/12/07	2	10¼	¼	1T
LL912	10	South Bay, Wexford	1/4/08	6	10⅞	⅞	1T
LL917	9½	Near Lytham Pier	13/12/07	2		—	2T
LL920	9½	Carmarthen Bay, 9 faths.	16/4/08	6	9¼	¼	1T
LL921	10	Red Wharf Bay, 10 faths.	10/12/07	2	10½	½	1T
LL939	9½	Off Mostyn, Dee, 8 faths.	10/1/08	2	9¼	¼	1T
LL944	11¼	49° 50′ N. : 8° W.	2/9/08	11	14½	3¼	ST

Experiment 1, 1908. Station: Barrow Channel, 7th April, 1908.

1	2	3	4	5	6	7	8
LL603	8½	Roosebeck Scar, Morecambe Bay.	30/4/08	1	8½	0	SN
LL607	9¼	Do. do.	21/4/08	1	9¼	0	SN
LL608	9	Do. do.	18/4/08	1	9	0	SN
LL610	9	Do. do.	4/5/08	1	9¼	¼	SN
LL611	9¼	Do. do.	20/4/08	1	9¼	0	SN
LL614	8¼	Barrow Channel	30/4/08	1	8¼	0	SN
LL622	9½	Roosebeck Scar, Morecambe Bay.	3/5/08	1	9¾	¼	SN
LL615	10	Do. do.	20/4/08	1	10	0	SN
LL829	9½	Do. do.	16/4/08	1	9½	0	SN
LL831	9	Do. do.	3/5/08	1	9½	½	SN
LL832	10	Do. do.	20/5/08	1	10½	½	SN
LL836	9½	Do. do.	3/4/08	1	9¾	¼	SN
LL837	8	Do. do.	1/4/08	1	8½	½	SN
LL840	8¼	Do. do.	4/5/08	1	8½	0	SN
LL953	8½	Do. do.	11/7/08	3	9	½	SN
LL962	9½	5 miles S.E. from Bahama Light Ship, 11 fathoms.	17/10/08	6	10	½	ST
LL966	9	Barrow Channel	30/4/08	1	9	0	2T
LL968	9¼	Roosebeck Scar, Morecambe Bay.	3/5/08	1	9⅜	⅛	SN
LL970	8¼	Do. do.	23/4/08	1	8¼	0	SN
LL971	9	Do. do.	2/5/08	1	9	0	SN
LL974	10	Do. do.	22/4/08	1	10	0	SN
LL975	11½	Do. do.	2/5/08	1	11½	0	SN
LL977	9	Do. do.	7/4/08	1	9	0	SN
LL979	8¾	Do. do.	4/5/08	1	8¾	0	SN
LL981	8	Do. do.	30/8/08	4	11	3	SN
LL982	8½	Do. do.	20/4/08	1	8½	0	SN
LL983	8¾	Do. do.	21/4/08	1	8¾	0	SN
LL984	8¾	Do. do.	3/5/08	1	9	¼	SN
LL985	9¾	Do. do.	22/4/08	1	9¾	0	SN
LL989	8½	Do. do.	3/5/08	1	9¾	1¼	SN
LL994	9	Barrow Channel	8/4/08	1	9	0	2T
LL995	8½	Roosebeck Scar, Morecambe Bay.	20/4/08	1	10	1½	0
E261	9¼	Do. do.	4/5/08	1	9½	¼	SN
E262	9½	Do. do.	21/4/08	1	9½	0	SN
E270	9½	Do. do.	16/4/08	1	9½	0	SN
E280	8¾	Do. do.	29/4/08	1	8¾	0	SN
E283	8¾	Do. do.	1/5/08	1	8¾	0	SN
E285	9	Do. do.	17/4/08	1	9	0	SN
E288	8¼	Do. do.	4/5/08	1	8¼	0	SN
E292	8½	Do. do.	1/5/08	1	8½	0	SN
E305	9½	Do. do.	16/5/08	1	9¾	¼	SN
E306	8¾	Do. do.	21/4/08	1	8¾	0	SN
E308	7½	Do. do.	16/4/08	1	7½	0	SN
E315	8	Do. do.	1/5/08	1	8	0	SN
E318	9	Do. do.	18/5/08	1	9	0	SN
E319	10	Do. do.	3/5/08	1	10	0	SN
E322	8½	Do. do.	5/5/08	1	9	½	SN
E324	8	Do. do.	17/4/08	1	8	0	SN
E327	8	Do. do.	21/4/08	1	8	0	SN
E328	9	Do. do.	22/4/08	1	9	0	SN
E329	10½	Do. do.	22/4/08	1	10½	0	SN
E339	8	Do. do.	22/4/08	1	8	0	SN

Experiment 2, 1908. Station: Luce Bay, 8th October, 1908.

1	2	3	4	5	6	7	8
LA30	13¼	Drummore, Luce Bay ...	16/11/08	1	13¼	0	GN

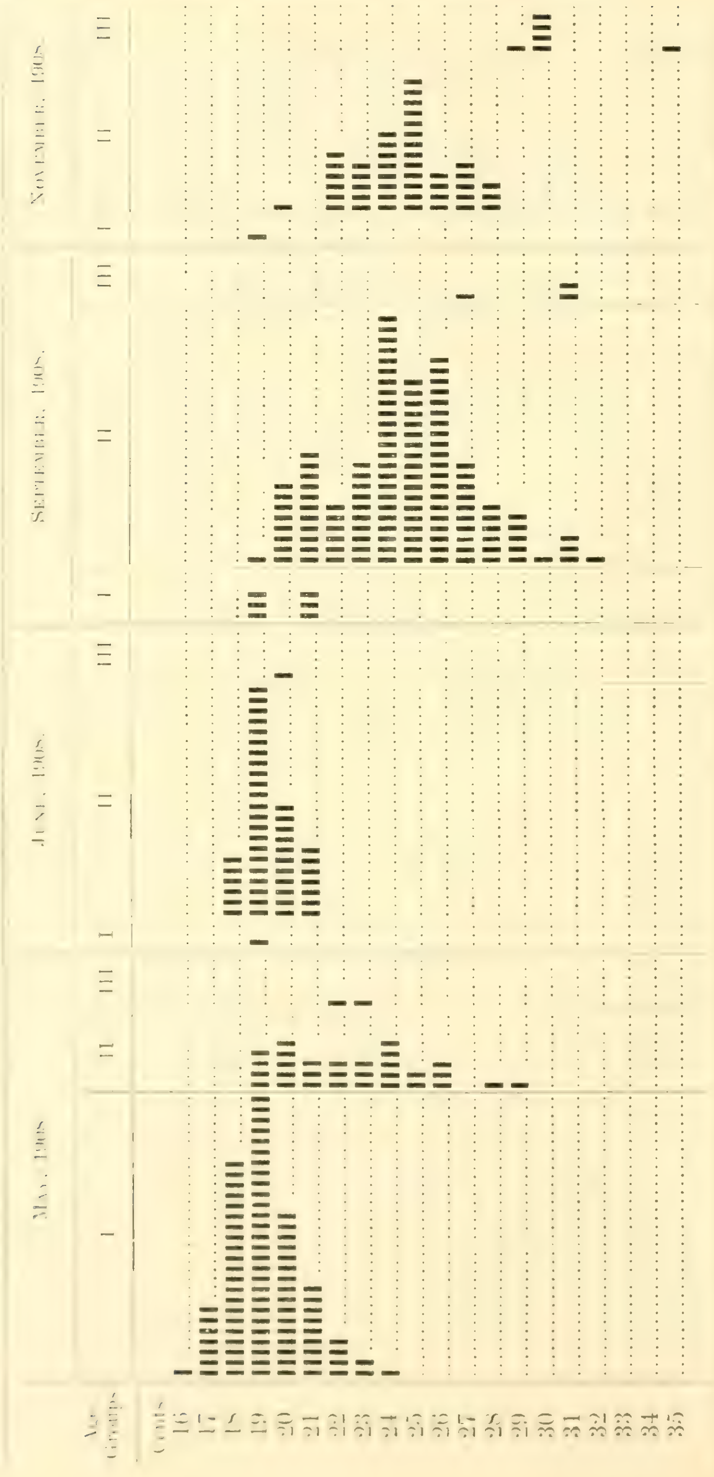
Speaking generally, the results are similar to those of former years. A certain small proportion of plaice have migrated (apparently for good) out from the Eastern part of the Irish Sea. Two of these instances are interesting. Plaice No. LL857 was recaptured off Waterford by the Ostend steam trawler "Jules Henri," O 115; and Plaice No. LL944 was retaken in N. Lat. 49° 50′, W. Long. 8°—that is, out from the mouth of the English Channel, by the Fleetwood steam trawler "Eulalia."

I may refer briefly to the results of Experiment 1 of 1908. It will be seen that, with one exception, the fishes returned have been recaptured in close proximity to the place of liberation, and mostly within two months after the date of the experiment. The latest date on which one of these fishes was recaptured in the Barrow area was 30th August, 1908. One fish has been returned since then, viz., LL962, recaptured near Bahama Bank Light Ship. When we made this experiment we expected that a considerable proportion of the marked plaice would be recaptured during April, May and June, but that, after the latter month, the migration seawards would begin, and that some of the larger fishes would be retaken on the grounds lying between the Morecambe Bay and Liverpool North-West Light Ships, during the summer; and in the Bahama Bank area, during the late autumn and winter. Now, none of these fishes has been taken on the former area, and only one on the latter area. This fish is the latest, belonging to the experiment, that has been returned up to the time of writing this report (December, 1908). The interpretation of these facts seems to be that the plaice inhabiting the Barrow Channel and neighbourhood have been a practically stationary fish population during the first three quarters, at least, of the year 1908. As a matter of fact, relatively enormous catches of plaice have been made on these grounds during the first half of the year. One tide's catch, made by one man working several stake nets, consisted of over half a ton of plaice. There were apparently great areas of sea-bottom in this locality covered by small, growing mussels, and this abundance of food led to the aggregation of the plaice in its neighbourhood. Towards the end of the year the fish of Age-group III have apparently begun to move out into deeper water, but throughout eight or nine months they have practically remained in the one locality.

This conclusion is supported by a study of the Age-groups of representative samples of plaice taken from the stake nets on Roosebeck Scars. These results are given in the table on page 126, which deals with the examination of four lots of fish.

It will be seen that the plaice examined in May belonged for the most part to the group over one and less than two years of age. In June, however, Age-group I practically disappears and the fish then belong to the group over two and less than three years of age, and with a modal size of 19 centimetres. In September Age-group I is also nearly absent, and the fish belong to Age-group II, but the modal size now lies between 24 and 25 centimetres. Again, in September Age-group II is the principal one represented, and the modal size is much about the same, perhaps a little greater. There are a few fishes in each catch belonging to Age-group III, but not many. Of course it might be the case that there was an immigration of plaice belonging to Age-groups II and III during the summer and autumn months, but I do not think this could have been extensive.

PLAICE MEASUREMENTS: BARROW CHANNEL, 1908.



PLAICE MEASUREMENTS MADE DURING 1908.

By Jas. Johnstone.

The following tables relate to the individual measurements of 21,000 plaice made during the year 1908, mainly during the months of July to December. The measurements were made on board the s.s. "James Fletcher," and on board the sailing cutters stationed at Fleetwood and New Brighton. Measuring boards, made after the pattern suggested by Professor D'Arcy W. Thompson, were used on the "James Fletcher." These boards are provided with cork inlaid between strips of celluloid, the latter marking centimetre divisions. Each fish is laid on the scale, and a brass ("lacemaker's") pin is stuck into the cork strip opposite to the centimetre division on which the tail of the fish lies. By this method the fish are measured rapidly and exactly, and it is not necessary to use a notebook to record the numbers. When the catch is measured the board is taken into the laboratory and read. For some reason or other, the Bailiffs on the sailing cutters prefer to use a notebook ruled in the usual way and with a centimetre scale written along the left-hand margins. A tick is put opposite the number called out as each fish is measured.

The method adopted in the International Fishery Investigations is also adopted here—that is, no fractions of a centimetre are recorded, and all fish measuring between (say) 15 and 15·9 cents. are regarded as measuring 15 cents. It is necessary to add 0·5 cm. to averages deduced from the measurements.

Table I contains the measurements of plaice caught off the Mersey estuary in a trawl-net of 6-inch mesh, and

Table II gives the measurements of plaice caught in the same area in a shrimp trawl of ½-inch mesh. In order to obtain the modal sizes both Tables should be combined. It is, however, more convenient to give the measurements separately. Table III exhibits the sizes of plaice caught in the channels in Morecambe Bay, also by a trawl-net of 6-inch mesh. These three Tables relate to the measurements of plaice caught by half-decked sailing boats. Table IV shows the measurements of plaice caught also in a trawl-net of 6-inch mesh, but worked from the steamer "James Fletcher." In all these Tables the hauls taken during the same months are combined.

Table V shows the results of the measurement and sex-determinations of rather over 1,000 plaice caught in Luce Bay on one day by the s.s. "James Fletcher," using an otter-trawl net of 40-feet spread, and of 7-inch mesh. The object of these hauls was to obtain mature plaice for hatching purposes, and therefore it was impossible to examine the fish for age-determinations.

Table VI shows the results of the examination of plaice caught during 1908, and gives the Age-groups based on the examination of the otoliths. Group I includes plaice between one and two years of age, II fish from two to three, and III fish from three to four years old.

Table VII is an attempt to express numerically what is meant by the term "condition of the fish." A number of plaice were measured individually, and the fish were then collected in centimetre groups and average weights were calculated.

The object of these measurements is two-fold: (1) a contribution to the life-history of the plaice in the Irish Sea; and (2) an attempt to study the changes which may possibly result from the relaxation of the trawling bye-laws introduced at the beginning of the present year. Formerly a trawl-net of 6-inch mesh was only allowed in certain places and at certain periods of the year, but since January, 1908, this form of trawl-net has become legal over all parts of the Lancashire and Western Sea Fisheries District. It is possible that the increase in catching power thus legalised may affect the density of plaice in local waters, but it is practically certain that the statistics of the fishery, as at present collected, could not be used so as to exhibit any such changes. It is indeed possible that the increase in catching power, brought about by allowing a 6-inch trawl mesh to be used everywhere, instead of only allowing it during a part of the year, and in a restricted area, may not be significant, for the natural productivity of the Irish Sea fishing grounds may easily bear this extra demand. But however this may be, it is probable that it is only by a study of the modal sizes of the plaice caught for the next two or three years, that any change in this productivity is to be detected. If there should be no such change, then we may be fairly sure that the relaxation of the restrictions on trawling and trawl-net meshes is not likely to be detrimental to the fishing grounds.

It would, of course, be premature to discuss these data at the present time, and they are collected and summarised here in order to save the time that would be spent in working them up if they were allowed to accumulate. It is also necessary to study the figures collected from time to time in order that any changes in methods suggested might be adopted.

I.—Off the Mersey Estuary. Fish-trawl. 6″ mesh.

Size in cms.	August.	September.	October.	November.	December.
11	3	1	—	—	1
12	12	3	1	—	2
13	99	33	5	1	17
14	294	232	17	3	70
15	611	660	173	42	187
16	705	879	452	109	276
17	493	571	348	78	208
18	232	293	307	63	129
19	124	179	199	32	78
20	110	166	159	19	88
21	74	112	141	21	70
22	48	111	104	29	66
23	31	61	85	18	31
24	21	33	48	8	26
25	4	26	53	9	20
26	2	13	27	5	9
27	—	9	22	1	5
28	—	1	17	2	1
29	2	—	12	—	2
30	—	—	3	—	—
31	—	1	1	—	—
32	—	1	1	1	—
33	—	2	—	—	—
34	—	—	1		—
35	—	—	—	—	—
36	—	—	—	—	—
37	1	2	—	—	—
38	—	2	—	—	—
39	—	1	—	—	—
40	—	—	—	—	—
Totals ...	2866	3392	2176	441	1286

II.—OFF THE MERSEY ESTUARY. Shrimp-trawl, $\frac{1}{2}''$ mesh.

Size in cms.	July.	September.	October.	December.
3	3	—	—	—
4	36	—	—	85
5	43	51	1	222
6	11	151	—	131
7	2	131	2	161
8	27	46	—	82
9	70	28	3	92
10	42	6	2	27
11	26	12	3	21
12	19	12	3	15
13	1	66	13	8
14	1	82	21	6
15	—	122	50	20
16	—	74	51	12
17	7	42	50	7
18	5	15	30	5
19	1	13	20	2
20	—	8	18	5
21	1	9	11	6
22	1	11	4	4
23	—	7	2	5
24	2	5	2	1
25	—	—	—	2
26	—	3	—	2
27	—	—	—	1
28	—	—	—	1
Totals ...	298	894	286	923

III.—Fleetwood Channel, Barrow Channel, Morecambe Bay. 6″ mesh.

Size in cms.	July.	August.	Sept.	October.	Nov.	December.
13	1	1	1	—	1	1
14	2	4	4	—	5	1
15	34	9	8	12	18	6
16	63	46	32	23	68	22
17	120	76	38	36	117	28
18	68	71	66	40	163	23
19	116	72	66	38	80	19
20	141	58	92	15	78	18
21	68	46	70	33	49	16
22	61	34	67	35	48	21
23	16	29	49	27	43	17
24	18	29	35	20	30	18
25	10	8	21	14	20	8
26	7	11	22	6	19	6
27	5	5	22	6	9	4
28	1	3	4	2	7	6
29	4	2	3	3	6	3
30	4	—	4	—	4	2
31	—	—	1	—	1	—
32	—	—	—	1	—	1
33	2	—	—	—	—	1
34	—	—	—	—	—	—
35	1	—	—	—	—	—
36	—	—	1	—	—	—
37	—	—	—	—	—	—
38	—	1	—	—	—	—
39	—	—	—	—	—	—
40	—	1	—	—	—	—
Totals ...	742	506	606	311	766	221

	IV.—Blackpool Closed Ground: near Nelson Buoy; near Jumbo Buoy. 6″ mesh.		Red Wharf Bay: Beaumaris Bay; Channel Course; Colwyn Bay. 6″ mesh.		Off New Quay Head, S. Wales.		
Size in cms.	Aug.	Oct.	Sept.	Nov.	May.	July.	Oct.
13	1	—	13	2	—	—	—
14	—	—	46	9	1	—	—
15	2	—	115	32	3	—	—
16	8	—	185	94	4	—	—
17	47	264	259	80	6	—	5
18	81	17	175	48	13	1	5
19	95	37	175	33	12	1	8
20	88	74	167	23	21	6	4
21	71	73	135	25	22	8	8
22	72	56	132	15	20	21	9
23	35	64	100	4	17	41	7
24	17	55	150	17	21	56	10
25	7	24	132	2	16	49	11
26	7	9	123	5	15	41	5
27	3	5	128	8	3	27	9
28	—	2	89	8	1	13	5
29	5	—	61	4	1	6	4
30	1	—	68	7	1	3	1
31	—	1	37	7	1	1	3
32	1	—	22	2	1	—	2
33	—	—	16	2	1	—	—
34	1	—	5	—	—	—	—
35	—	—	10	(41) 3	—	—	1
36	—	1	2	1 (44) 1	—	—	—
37	—	—	1	2 (45) 2	—	—	—
38	—	—	2	(47) 1	—	—	—
39	—	—		2	—	—	1
40	—	—	—	2	—	—	—
Totals	542	682	2348	441	180	274	98

V.—Luce Bay. 7″ Trawl-net. Six Hauls, 7th October, 1908.

Size in cms.	♂	♀	Total.	Size in cms.	♂	♀	Total.
12	1	1	2	38	12	27	39
13	1	–	1	39	9	24	33
14	1	1	2	40	6	19	25
15	3	1	4	41	—	16	16
16	9	8	17	42	1	24	25
17	19	23	42	43	1	10	11
18	28	16	44	44	–	13	13
19	29	39	68	45	–	3	3
20	35	37	72	46	2	5	7
21	29	36	65	47	—	1	1
22	19	20	39	48	—	2	2
23	18	13	31	49	1	1	2
24	17	10	27	50	—	3	3
25	17	16	33	51	—	2	2
26	9	11	20	52	—	—	—
27	5	16	21	53	—	—	—
28	13	14	27	54	—	—	—
29	6	8	14	55	–	—	—
30	15	12	27	56	—	—	–
31	7	7	14	57	—	—	—
32	21	17	38	58		1	1
33	30	25	55	59	—	—	—
34	24	23	47	60	–	—	—
35	31	24	55	61	—	—	—
36	26	30	56	62	—	1	1
37	18	30	48				
				Totals	463	590	1053

VI.—SIZES AND AGES OF PLAICE. MORECAMBE BAY, BLACKPOOL, NELSON BUOY.

SEX.	FEMALES.			MALES.		
Age-group	I	II	III	I	II	III
Size, cms.						
12	—	1	—	—	—	—
13	4	1	—	4	—	—
14	8	—	—	8	—	—
15	18	4	—	26	6	—
16	31	5	—	16	12	—
17	28	13	—	21	24	—
18	18	25	—	20	45	—
19	23	63	—	21	24	—
20	16	41	1	14	34	9
21	8	27	4	10	28	—
22	3	19	2	3	21	—
23	3	19	6	1	13	2
24	—	29	1	1	24	—
25	—	19	1	—	17	3
26	1	16	2	—	11	1
27	—	8	3	—	10	2
28	—	4	1	—	6	1
29	—	4	1	—	2	2
30	—	—	7	—	1	2
31	—	—	—	—	3	1
32	—	1	2	—	1	1
33	—	—	—	—	—	—
34	—	—	—	—	—	—
35	—	—	—	—	—	1
36	—	—	—	—	—	—
37	—	1	—	—	—	—
Totals ...	161	300	31	145	282	25

VII.—LENGTH AND WEIGHT OF PLAICE.

				JULY.			SEPTEMBER.		
BARROW CHANNEL.*				LUNE AND WYRE.			RED WHARF BAY.		
Size cms.	No. of Fish.	Average Weight.	*k*.†	No. of Fish	A'v'g W'ght.	*k*.	No. of Fish.	A'v'g W'ght.	*k*.
15	—	—	—	8	44	1·26	43	40	1·15
16	—	—	—	17	52	1·27	49	47	1·14
17	8	58	1·18	28	59	1·20	44	57	1·16
18	20	66	1·13	27	71	1·21	14	71	1·21
19	31 (4)	76 (87)	1·10 (1·26)	20	75	1·09	14	78	1·13
20	21 (8)	85 (95)	1·06 (1.18)	17	90	1·12	22	88	1·10
21	12 (12)	96 (111)	1·03 (1·2)	11	99	1·06	22	98	1·05
22	8 (6)	108 (119)	1·01 (1·11)	8	127	1·19	11	114	1·07
23	7 (9)	136 (143)	1·12 (1·17)	4	117	0·96	8	131	1·07
24	6 (20)	144 (158)	1·04 (1·14)	—	—	—	9	147	1·06
25	(14)	(185)	(1·18)	—	—	—	7	161	1·03
26	3 (16)	192 (200)	1·09 (1·13)	—	—	—	8	192	1·09
27	(10)	(250)	(1·27)	—	—	—	6	195	0·99
28	(4)	(274)	(1·24)	—	—	—	—	—	—
29	—	—	—	—	—	—	—	—	—
30	—	—	—	—	—	—	—	—	—
31	(3)	(322)	—	—	—	—	—	—	—

* Figures without brackets refer to May measurements. Figures enclosed in brackets refer to September measurements.

† The coefficient $k = \frac{100\,w}{l^3}$. w = weight, and l = length, both in metric units.

PLATE I.

S.S. "JAMES FLETCHER."

DESCRIPTION OF THE FISHERIES CRUISER, "JAMES FLETCHER."

By Capt. A. Wignall and Jas. Johnstone.

The "James Fletcher" is a schooner-rigged, twin-screw steamer. Her dimensions are as follows: Length between perpendiculars, 139 feet 6 inches; beam 23 feet; draft forward, 8 feet; draft aft, 11 feet. She was built by Messrs. Phillip & Sons, Dartmouth, in 1907.

There are two sets of triple-expansion, inverted, direct-acting, surface-condensing engines. The cylinders are two of 10 inches, two of 16 inches, and two of 26 inches. The stroke is 20 inches; and the indicated horse-power is 600, capable of driving the vessel at a speed of twelve knots. There is no forced draught. The boiler was made by Messrs. Richardson & Westgarth, Middlesborough. It is about 14 feet 3 inches by 10 feet 6 inches, with three furnaces stoked forward; multitubular, and with a working pressure of 185 lbs. It is fitted with Brundret's Temperature Balance for automatic water circulation.

The gross tonnage is 263·61, and the deductions are 238 tons. It is obvious from these figures that there is plenty of accommodation on board. In fact, accommodation is found for a crew of twelve officers and men; and there are cabins for the Master and Superintendent, three scientific men, and two members of Committee, or guests. There is a large dining saloon forward, and a messroom aft for the crew. The mate, engineers, and boatswain have sleeping accommodation aft, and the cook, steward, deckhands and stokers sleep in a commodious forecastle. There is a large chart-room on the deck forward, providing plenty of room for clerical

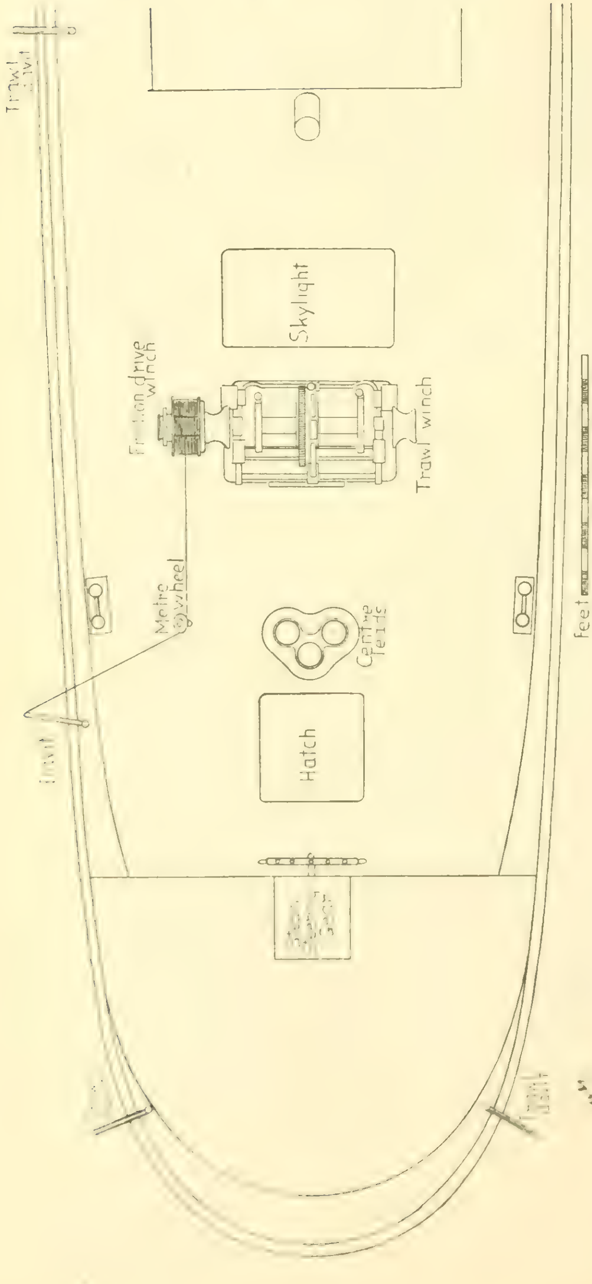


Fig. 1.—Plan of main deck of s.s. "James Fletcher."

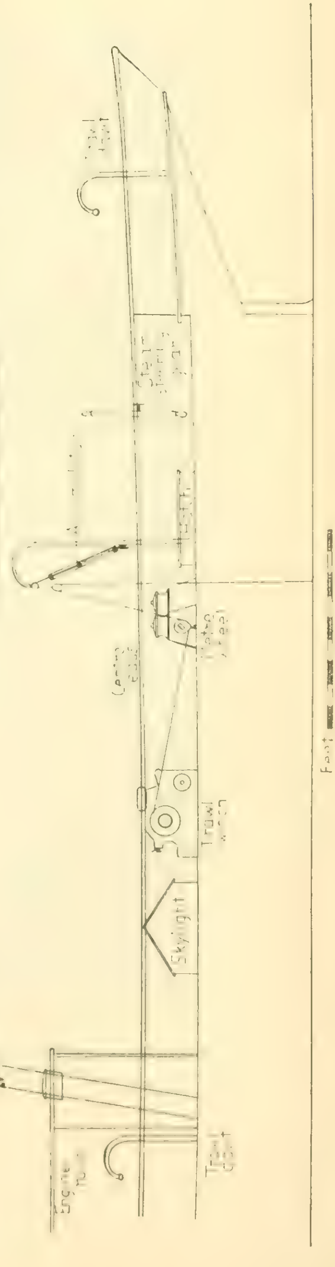


Fig. 2.—Elevation, port side after part of s.s. "James Fletcher."

work, and also room for scientific work of a more delicate character. There is a bridge-deck over the chart-room, on which is a wheel-house. The ship is fitted with electric light throughout, electric side, and mast-head lights, and with a powerful searchlight, which is placed on the bridge-deck forward. There are strong portable lights for use in the laboratory, and below hatches, and also for use on deck when trawling or doing scientific work in the dark. The vessel is provided with steam steering gear, the steering engines being situated aft over the rudder head.

The laboratory is aft, and is provided with plenty of storage accommodation, bottle racks, cabinets for the storage of specimen bottles and tubes, lockers, drawers and cupboards. Beneath the laboratory is a large storeroom entered through a hatch. This is used for the storage of the more bulky scientific apparatus. Behind the laboratory is a large storeroom, entered through a hatch on the main deck. This is used for the storage of trawling gear, &c. There is a large dissecting table in the laboratory, and a smaller table provided with a large sink. Fresh water is laid on. Rough work, such as measuring and gutting fish, is done on the main deck in the lee of the deck-house. There is a large tub on the deck which can be kept filled with sea water from a pump, and portable tank accommodation is provided by means of which a fairly large number of fish can be kept alive.

The vessel carries an otter-trawl on the port side, and a beam-trawl on the starboard side. The hauling gear consists of a large trawl winch on the main deck, on to which can be fitted an accessory friction-drive winch, which has several drums, each carrying a special steel wire.* These are used for working the lighter apparatus, such as water bottles, thermometers, plankton nets, &c. There is a derrick on the mainmast, and a single davit on the main deck aft. These are used for working lighter fishing gear, and other scientific apparatus. Shrimp trawl and shank nets are also carried.

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* This winch was ingeniously designed and constructed by Messrs. Robertson & Sons, Engineers, Fleetwood.

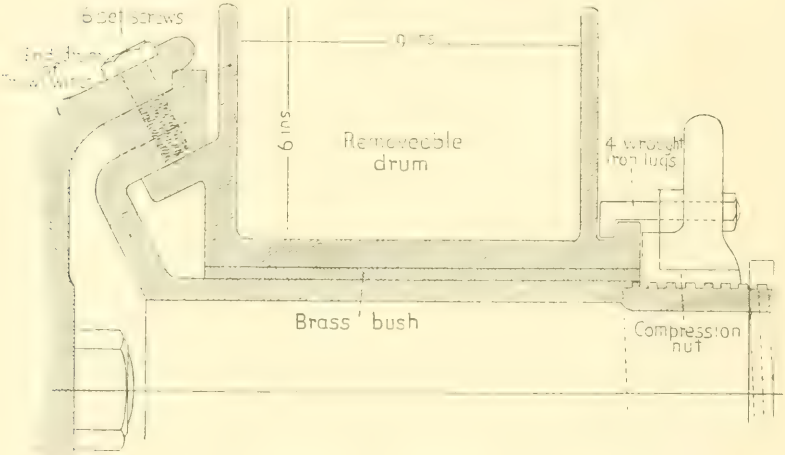

Fig. 3.—Section of Friction-drive Accessory Winch.

The scientific apparatus includes:—Two large vertical Hensen nets; two medium vertical Hensen nets; two large vertical egg-nets: these are Hensen nets constructed with coarse silk; two shear-nets (this is the Helgoland "Scherbrutnetz"); Petersen's "Yngel-trawl"; ordinary surface tow-nets, of course; the small Nansen-Pettersson water-bottle, used in the International Fishery Investigations, with reversing thermometer frame, and thermometer: and with a set of four Nansen deep-water thermometers, all provided with the Charlottenburg certificates. Surface thermometers, and a set of the Kiel hydrometers and thermometer, are carried. Wet and dry bulb air thermometers are fixed on the deck-house aft. A self-recording barometer is hung on springs in the chart-room. Other meteorological apparatus is not yet provided.

Sounding is carried on, when scientific work is being done, by means of the smaller Lucas Automatic Sounding Machine. This is fixed on a portable bracket which is carried on the rail just forward of the bridge deck. Lighter apparatus, such as thermometer frames, can be worked from the steel wire of the sounding machine. Instead of the ordinary pianoforte wire usually employed with this machine, a strand of seven No. 25 galvanised steel wires is used with twenty-pound leads.

The Nansen-Pettersson water-bottle is worked by means of a steel wire rope, consisting of six strands each of eighteen wires, and coreless. The rope is half an inch in circumference, and has a breaking strain of 35 cwts. This is stronger than is required for the water-bottle, but the wire rope can also be used for the pelagic nets, and economy of apparatus is secured. The wire is carried on a portable drum which is fitted on to the accessory winch. The wire passes from the latter (see figs. 1 and 2) aft to the metre-wheel, which hooks on to a detachable screw eye-bolt let into a socket on the deck. The wire then passes over a snatch block at the davit head. The drum of the accessory winch is a "free-wheel" which runs out easily. When the bottle is hauled a collar with projecting lugs is tightened against the end of the drum, and the latter is worked by starting the trawl winch. The defect of this arrangement is, of course, that the drum cannot be revolved very rapidly. In a sounding in water of 145 fathoms about six minutes were required to haul the apparatus, but since the great majority of hydrographic soundings to be made in the Irish Sea deal with water of twenty to forty fathoms in depth, this slowness of hauling is a matter of no importance.

The Nansen-Pettersson water-bottle has given every satisfaction. An occasional difficulty in locking was remedied by the adjustment of the catches on the lateral rods, and by close attention to the cleanness of the latter. The closure of this water-bottle is very complete. When it has been locked it has been found impossible to open it even when the catches at the sides are loosed, until the valve at the top is opened. It would be an advantage if the copper wire ropes carrying the weight could be replaced by chains, for the wires of these ropes are apt to break and cut the hands of those working the apparatus.

With this apparatus it is found possible to take hydrographic soundings even in a fairly rough sea. Soundings are always made on the windward side of the vessel and with the wind about three to five points on the port side (on which the davit is placed). Careful manœuvring of the vessel is, of course, necessary, but we have very seldom found the weather bad enough to prevent the work being done. In a rough sea it is necessary to make allowance for the rise and fall due to the heave of the ship, in converting the fathoms of depth indicated by the sounding machine into metres (which are indicated on the metre wheel). It would be an advantage in practical working if the Lucas machines were made to indicate metres, and if the gearing of the clock were made to indicate units and tens on different dials. Sounding machine and metre wheel give almost identical readings, and when only one or two metres are allowed for clearance from the sea bottom, it is often found that the pitching of the vessel in a seaway is sufficient to make the water-bottle weight just touch the bottom.

Ordinary surface tow-nets are hauled from forward on the windward side of the vessel. It has been found that it is undesirable to use the tow-nets over the stern on account of the mixing of the layers of water caused by the propellers. It is also bad practice to tow the net directly from the ship's side. It is very desirable to use the net always on the windward side. There appears to be a difference in the plankton taken to windward and leeward—that is if the ship is making any leeway. A small otter-board of about two feet square is trimmed so as to tow well out from the ship's side, and the tow-nets are fastened to this. By this arrangement the net tows about five or six feet out from the side, and it is practically unaffected by rolling or pitching which, when the net is towed from a rope fastened to the side directly, are apt to cause the net partially to rise out of the water, and vice versa.

Deep hauls with the ordinary tow-net were formerly made simply by attaching the net to the back of the trawl, using a short rope so that the net could not roll off the latter. But this did not, of course, give a really bottom sample. It was useful for securing a rough sample of the general plankton contents of the water, and this is, of course, all that can be expected from hauls taken by means of nets unprovided with conical head pieces. By far the most accurate means of exploring the vertical distribution of the plankton is that of taking samples of the water at different depths by means of the water-bottle, and we have practised this on many occasions. Unfortunately the capacity of the Nansen-Pettersson bottle is too small in general to afford a big catch. It would be an advantage if some water-bottle were designed for this purpose alone. Kofoid has indeed suggested a form of water-bottle for collecting plankton, but the apparatus appears to us to be rather costly.

The vertical nets are worked in the same manner and by the same gear as in the case of the water-bottle. The net after being hauled is washed on the outside by means of the hose, and the contents of the bucket are run through a small piece of silk of the same mesh as that employed in the construction of the net itself. This silk filter is sprung on to the end of a short brass collar, two and a half inches in diameter, and the same in depth, by means of a strong rubber band. The catch remains on the silk and partly on the sides of the brass collar. The silk is then unfastened and either placed at once in the bottle of preservative or it is held up by one corner and the catch is washed off by a stream of preservative from a wash bottle; and the small quantity of plankton adhering to the sides of the collar is likewise washed off. All bottles employed are marked by a number painted on the outside, and this number is entered on the form recording the condition under which the catch was made. Possibility of confusion of the catches, and the necessity of writing labels which are apt to come off, are thus obviated. It has been found to be a bad plan to insert a numbered paper label in the bottle containing the catch, as some of the finer plankton organisms are sure to adhere to the paper. The preservative fluid always used is $2\frac{1}{2}$ per cent. commercial formalin in sea water.

The "Scherbrutnetz" is worked from the same gear as in the case of the vertical nets. It is found that the wire rope referred to above is strong enough to haul these nets. The rope passes round the metre-wheel as before and over a snatch block at the single davit head, and then over a block on the after trawling davit on the port side. The height of this davit head above the surface of the water is known; the length of wire run out is also recorded on the metre-wheel. A messenger is fastened to the end of a metre tape-line and allowed to slide down the rope till it touches the water. The length of rope between the water surface and the block is then recorded, and from these data the depth at which the net is towing is easily calculated:

$$\frac{\text{Total length of rope out*}}{\text{depth of net}} = \frac{\text{length of rope above water}}{\text{height of davit head}},$$

assuming, of course, that the line is straight; and with a thin wire rope, and the comparatively heavy strain of hauling the net with its shear-board, the deviation from the straight may be neglected.

The metre wheel is read when the net is first in the water, and then again when the haul begins.

REPORT ON THE HYDROGRAPHIC WORK IN THE IRISH SEA DURING 1908.

By HENRY BASSETT, Jun., D.Sc., Ph.D., Assistant Lecturer in Chemistry in the University of Liverpool.

The hydrographic work begun in 1906* has been continued along similar lines during the last year.

Samples were collected during February, May, July and October from the ten stations situated on the line running from Piel Gas Buoy to Calf of Man to Holyhead, and thence across Carnarvon and Cardigan Bays. The positions of the stations are shown on the chart on p. 168. In June a special trip was made to study the deep water to the West of the Isle of Man and off the Mull of Galloway. As on previous occasions, the water samples have been collected by my colleague Mr. James Johnstone, only the analyses being carried out by myself. The equipment of the steamer "James Fletcher," from which the observations were made, is described by Captain Wignall in a separate paper.

Full details of the various observations are given in the following tables. The first column gives the depth in metres; T° is the temperature (Centigrade) of the water *in situ*; Cl is the amount of chlorine per 1000 parts of water as found by the titration; S °/₀₀ is the salinity; and $1 + \frac{\sigma_t}{1000}$ gives the density of the sample of water at the temperature T. The position of the station and the date on which the samples were collected are given above each table.

The present Report concludes with a discussion of several general conclusions which can be drawn from the results of the hydrographic work carried out during the three years 1906 to 1908.

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* See Trans. Biological Society of Liverpool. Vol. XXII, 1908, pp. 51-79.

Feb. 25, 1908.

Station I. (8.15 a.m.) 54° N.; 3° 30′ W. Depth of station, 23·8 metres.

Depth (metres)	T°	Cl °/₀₀	S °/₀₀	σ_t
0	5·2	18·08	32·66	25·83
10	5·1	18·08	32·66	25·84
22	5·1	18·11	32·72	25·89

Station II. (9.15 a.m.) 54° N.; 3° 47′ W. Depth of station, 34·7 metres.

Depth (metres)	T°	Cl °/₀₀	S °/₀₀	σ_t
0	5·5	18·14	32·77	25·88
10	5·2	18·14	32·77	25·92
33	5·3	18·18	32·84	25·97

Station III. (10.10 a.m.) 54° N.; 4° 4′ W. Depth of station, 40·2 metres.

Depth (metres)	T°	Cl °/₀₀	S °/₀₀	σ_t
0	5·8	18·32	33·10	26·11
10	5·5	18·33	33·12	26·15
36·6	5·5	18·33	33·12	26·15

Station IV. (11.15 a.m.) 54° N.; 4° 20′ W. Depth of station, 42 metres.

Depth (metres)	T°	Cl °/₀₀	S °/₀₀	σ_t
0	5·9	18·46	33·35	26·28
10	5·7	18·44	33·31	26·28
36·6	5·6	18·45	33·33	26·30

Station V. (12.50 p.m.) 53° 53′ N.; 4° 46′ W. Depth of station, 56·7 metres.

Depth (metres)	T°	Cl °/$_{oo}$	S °/$_{oo}$	σ_t
0	7·3	18·97	34·27	26·83
20	7·3	18·94	34·22	26·78
40	7·2	18·95	34·23	26·81
55	7·2	18·95	34·23	26·81

Station VI. (1.50 p.m.) 53° 43′ N.; 4° 44′ W. Depth of station, 62·2 metres.

Depth (metres)	T°	Cl °/$_{oo}$	S °/$_{oo}$	σ_t
0	7·1	19·04	34·40	26·96
20	7·0	19·00	34·33	26·91
40	7·0	19·01	34·34	26·93
55	7·0	19·02	34·36	26·94

Station VII. (2.50 p.m.) 53° 33′ N.; 4° 41′ W. Depth of station, 49·4 metres.

Depth (metres)	T°	Cl °/$_{oo}$	S °/$_{oo}$	σ_t
0	7·3	19·03	34·38	26·94
20	7·0	19·02	34·36	26·94
45·7	7·0	19·02	34·36	26·94

May 13 to 15, 1908.

Station I. 15/5/08 (10.45 a.m.) 54° N.; 3° 30′ W. Depth of station, 29·2 metres.

Depth (metres)	T°	Cl °/$_{oo}$	S °/$_{oo}$	σ_t
0	8·95	17·88	32·30	25·03
10	8·85	17·96	32·45	25·16
27·5	8·4	18·05	32·61	25·38

Station II. 15/5/08 (9.45 a.m.) 54° N.; 3° 47′ W. Depth of station, 40·2 metres.

Depth (metres)	T°	Cl $^\circ/_{oo}$	S $^\circ/_{oo}$	σ_t
0	8·85	18·23	32·94	25·54
10	8·4	18·27	33·01	25·68
38	7·9	18·50	33·42	26·14

Station III. 15/5/08 (8.40 a.m.) 54° N.; 4° 4′ W. Depth of station, 40·2 metres.

Depth (metres)	T°	Cl $^\circ/_{oo}$	S $^\circ/_{oo}$	σ_t
0	8·1	18·61	33·62	26·21
10	8·0	18·61	33·62	26·22
38	7·95	18·61	33·62	26·22

Station IV. 15/5/08 (7.45 a.m.) 54° N.; 4° 20′ W. Depth of station, 45·7 metres.

Depth (metres)	T°	Cl $^\circ/_{oo}$	S $^\circ/_{oo}$	σ_t
0	8·25	18·79	33·95	26·44
10	8·0	18·79	33·95	26·48
44	8·0	18·80	33·96	26·49

Station V. 14/5/08 (10.55 a.m.) 53° 53′ N.; 4° 46′ W. Depth of station, 82·3 metres.

Depth (metres)	T°	Cl $^\circ/_{oo}$	S $^\circ/_{oo}$	σ_t
0	8·2	18·96	34·25	26·68
10	8·1	18·96	34·25	26·70
30	8·0	18·96	34·25	26·71
80·5	8·0	18·95	34·23	26·70

Station VI. 14/5/08 (9.55 a.m.) 53° 43′ N.; 4° 44′ W. Depth of station, 64 metres.

Depth (metres)	T°	Cl °/oo	S °/oo	σ_t
0	8·35	18·90	34·14	26·58
10	8·0	18·90	34·14	26·63
30	7·95	18·89	34·13	26·61
62	7·95	18·88	34·11	26·60

Station VII. 14/5/08 (8.50 a.m.) 53° 33′ N.; 4° 41′ W. Depth of station, 54·8 metres.

Depth (metres)	T°	Cl °/oo	S °/oo	σ_t
0	8·3	18·85	34·05	26·50
10	8·1	18·85	34·05	26·54
30	8·1	18·85	34·05	26·54
53	8·2	18·85	34·05	26·52

Station VIII. 13/5/08 (8.15 p.m.) 53° 5′ N.; 4° 44′ W. Depth of station, 79 metres.

Depth (metres)	T°	Cl °/oo	S °/oo	σ_t
0	8·1	19·04	34·40	26·81
10	8·2	19·05	34·42	26·79
40	8·2	19·04	34·40	26·79
77·5	8·15	19·05	34·42	26·80

Station IX. 13/5/08 (5.15 p.m.) 52° 34′ N.; 4° 45′ W. Depth of station, 42 metres.

Depth (metres)	T°	Cl °/oo	S °/oo	σ_t
0	9·7	18·97	34·27	26·46
10	8·9	18·96	34·25	26·57
20	8·6	18·97	34·27	26·64
40	8·6	18·97	34·27	26·64

Station X. 13/5/08 (4 p.m.) 52° 24′ N.; 4° 43′ W. Depth of station, 42 metres.

Depth (metres)	T°	Cl °/₀₀	S °/₀₀	σ_t
0	9·9	18·98	34·29	26·55
10	8·8	18·98	34·29	26·61
20	8·7	18·98	34·29	26·62
40	8·7	18·97	34·27	26·61

The following surface samples were also collected during the May trip (**on May 12th**) :—

Time.	Position.	T°	Cl °/₀₀	S °/₀₀	σ_t
9.40 a.m.	53° 56′ N.; 3° 16′ W.	10·0	17·42	31·47	24·20
11.20 a.m.	53° 40′ N.; 3° 32′ W.	10·0	18·18	32·84	25·30
2.50 p.m.	53° 25′ N.; 3° 48′ W.	8·15	18·29	33·04	25·75

The following tables (June 16 to 19, 1908) refer to a special cruise made from Anglesey to Kingstown, then towards Port Erin and Mull of Galloway, and along Beauforts Dyke, the deep gutter between Ireland and Wigtownshire.

June 16 to 19, 1908.

16/6/08 (9.40 a.m.) 53° 22′ N.; 4° 54′ W. Depth of station, 51·2 metres.

Depth (metres)	T°	Cl °/₀₀	S °/₀₀	σ_t
0	9·6	18·99	34·31	26·53
10	9·4	18·99	34·31	26·58
50	9·4	18·99	34·31	26·58

16/6/08 (11.30 a.m.) 53° 22′ N.; 5° 14′ W. Depth of station, 100·6 metres.

Depth (metres)	T°	Cl °/oo	S °/oo	σ_t
0	9·7	18·98	34·29	26·48
10	9·5	18·97	34·27	26·50
98	9·4	18·97	34·27	26·52

16/6/08 (12.30 p.m.) 53° 20′ N.; 5° 29′ W. Depth of station, 107·9 metres.

Depth (metres)	T°	Cl °/oo	S °/oo	σ_t
0	9·7	18·94	34·22	26·42
10	9·5	18·93	34·20	26·44
103	9·4	18·95	34·23	26·49

17/6/08 (9.30 a.m.) 53° 33′ N.; 5° 39′ W. Depth of station, 100·6 metres.

Depth (metres)	T°	Cl °/oo	S °/oo	σ_t
0	10·4	—	—	—
10	10·3	18·82	34·00	26·14
75	7·9	18·92	34·18	26·67
100	7·9	18·93	34·20	26·68

17/6/08 (12 noon). 53° 53′ N.; 5° 9′ W. Depth of station 67·6 metres.

Depth (metres)	T°	Cl °/oo	S °/oo	σ_t
0	10·2	18·86	34·07	26·23
10	10·0	18·86	34·07	26·26
30	9·1	18·94	34·22	26·52
65	8·4	18·94	34·22	26·62

18/6/08 (9.20 a.m.) 54° 25′ N.; 4° 56′ W. Depth of station, 109·7 metres.

Depth (metres)	T°	Cl °/oo	S °/oo	σ_t
0	10·2	—	—	—
10	10·1	18·82	34·00	26·18
50	9·3	18·84	34·04	26·34
105	7·95	18·89	34·13	26·61

18/6/08 (10.50 a.m.) 54° 34′ N.; 5° 0′ W. Depth of station, 266·9 metres.

Depth (metres)	T°	Cl °/oo	S °/oo	σ_t
0	10·25	18·64	33·68	25·90
10	10·5	18·66	33·71	25·89
100	9·5	18·72	33·82	26·15
220	9·2	18·76	33·89	26·24

18/6/08 (2.20 p.m.) 54° 50′ N.; 5° 19′ W. Depth of station, 248·6 metres.

Depth (metres)	T°	Cl °/oo	S °/oo	σ_t
0	9·4	—	—	—
10	8·95	18·80	33·96	26·33
100	8·8	18·84	34·04	26·42
240	8·75	18·84	34·04	26·42

19/6/08 (10.40 a.m.) 54° 43′ N.; 4° 44′ W. Depth of station, 17·8 metres.

Depth (metres)	T°	Cl °/oo	S °/oo	σ_t
0	10·7	—	—	—
5	10·6	18·61	33·62	25·81
15	10·5	18·61	33·62	25·82

July 27 and 28, 1908.

Station I. 27/7/08 (11.15 a.m.) 54° N.; 3° 30′ W. Depth of station, 27·4 metres.

Depth (metres)	T°	Cl °/oo	S °/oo	σ_t
0	15·4	18·15	32·79	24·22
10	14·9	18·14	32·77	24·30
27	13·85	18·36	33·17	24·83

Station II. 27/7/08 (12.15 p.m.) 54° N.; 3° 47′ W. Depth of station, 40·2 metres.

Depth (metres)	T°	Cl °/oo	S °/oo	σ_t
0	14·15	18·38	33·21	24·80
10	13·9	18·36	33·17	24·83
40	12·85	18·62	33·64	25·39

Station III. 27/7/08 (1.15 p.m.) 54° N.; 4° 4′ W. Depth of station, 40·2 metres.

Depth (metres)	T°	Cl °/oo	S °/oo	σ_t
0	12·9	18·79	33·95	25·63
10	12·8	—	—	—
38	12·7	18·79	33·95	25·67

Station IV. 27/7/08 (2.15 p.m.) 54° N.; 4° 20′ W. Depth of station, 45·7 metres.

Depth (metres)	T°	Cl °/oo	S °/oo	σ_t
0	13·0	18·84	34·04	25·68
10	12·75	—	—	—
44	12·7	18·83	34·02	25·73

Station V. 27/7/08 (4 p.m.) 53° 53′ N.; 4° 46′ W. Depth of station, 84·1 metres.

Depth (metres)	T°	Cl °/oo	S °/oo	σ_t
0	13·43	18·85	34·05	25·61
10	13·1	—	—	—
30	11·2	18·86	34·07	26·05
80	12·0	18·89	34·13	25·93

Station VI. 27/7/08 (5.15 p.m.) 53° 43′ N.; 4° 44′ W. Depth of station, 45·7 metres.

Depth (metres)	T°	Cl °/oo	S °/oo	σ_t
0	12·6	18·90	34·14	25·85
10	12·4	—	—	—
30	12·35	18·88	34·11	25·85
42	12·35	18·88	34·11	25·85

Station VII. 27/7/08 (6.20 p.m.) 53° 33′ N.; 4° 41′ W. Depth of station, 65·8 metres.

Depth (metres)	T°	Cl °/oo	S °/oo	σ_t
0	12·95	18·90	34·14	25·80
10	12·75	—	—	—
30	12·6	18·90	34·14	25·85
65	12·6	18·90	34·14	25·85

Station VIII. 28/7/08 (9.55 a.m.) 53° 5′ N.; 4° 44′ W. Depth of station, 60·3 metres.

Depth (metres)	T°	Cl °/oo	S °/oo	σ_t
0	12·95	19·05	34·42	25·96
10	12·65	—	—	—
40	12·6	19·04	34·40	26·03
59	12·6	19·02	34·36	26·00

Station IX. 28/7/08 (1.10 p.m.) 52° 34′ N.; 4° 45′ W. Depth of station, 34·7 metres.

Depth (metres)	T°	Cl ‰	S ‰	σ_t
0	14·35	19·00	34·33	25·62
10	13·4	19·00	34·33	25·82
20	13·4	—	—	—
30	13·35	19·11	34·52	25·97

Station X. 28/7/08 (2.10 p.m.) 52° 24′ N.; 4° 43′ W. Depth of station, 34·7 metres.

Depth (metres)	T°	Cl ‰	S ‰	σ_t
0	14·5	19·00	34·33	25·59
10	13·8	18·99	34·31	25·77
20	13·65	—	—	—
31	13·65	19·00	34·33	25·80

October 26 to 28, 1908.

Station I. 26/10/08 (2.20 p.m.) 54° N.; 3° 30′ W. Depth of station, 27·4 metres.

Depth (metres)	T°	Cl ‰	S ‰	σ_t
0	12·8	17·93	32·39	24·45
10	12·5	—	—	—
26	12·8	18·46	33·35	25·19

Station II. 26/10/08 (3.20 p.m.) 54° N.; 3° 47′ W. Depth of station, 36·5 metres.

Depth (metres)	T°	Cl ‰	S ‰	σ_t
0	13	18·78	33·93	25·58
10	12·95	—	—	—
35	12·9	18·80	33·96	25·64

Station III. 26/10/08 (4.20 p.m.) 54° N.; 4° 4′ W. Depth of station, 38·4 metres.

Depth (metres)	T°	Cl °/₀₀	S °/₀₀	σ_t
0	12·8	18·87	34·09	25·76
10	12·8	—	—	—
37	12·75	18·85	34·05	25·73

Station IV. 26/10/08 (5.20 p.m.) 54° N.; 4° 20′ W. Depth of station, 42 metres.

Depth (metres)	T°	Cl °/₀₀	S °/₀₀	σ_t
0	12·8	18·82	34·00	25·67
10	12·8	—	—	—
40	12·8	18·82	34·00	25·67

Station V. 27/10/08 (9.30 a.m.) 53° 53′ N.; 4° 46′ W. Depth of station, 74·9 metres.

Depth (metres)	T°	Cl °/₀₀	S °/₀₀	σ_t
0	12·8	18·85	34·05	25·73
10	12·75	—	—	—
30	12·75	18·84	34·04	25·72
73	12·8	18·84	34·04	25·72

Station VI. 27/10/08 (10.30 a.m.) 53° 43′ N.; 4° 44′ W. Depth of station, 69·5 metres.

Depth (metres)	T°	Cl °/₀₀	S °/₀₀	σ_t
0	13·1	18·92	34·18	25·76
10	13·05	—	—	—
30	13·05	18·90	34·14	25·75
65	13·05	18·89	34·13	25·73

Station VII. 27/10/08 (11.40 a.m.) 53° 33′ N.; 4° 41′ W. Depth of station, 62·1 metres.

Depth (metres)	T°	Cl °/oo	S °/oo	σ_t
0	13·5	18·83	34·02	25·57
10	13·5	—	—	—
30	13·5	18·82	34·00	25·55
60	13·5	18·81	33·98	25·54

Station VIII. 27/10/08 (2.20 p.m.) 53° 5′ N.; 4° 44′ W. Depth of station, 53 metres.

Depth (metres)	T°	Cl °/oo	S °/oo	σ_t
0	13·75	19·16	34·61	25·97
10	13·75	—	—	—
20	13·8	19·14	34·58	25·94
50	13·8	19·14	34·58	25·94

Station IX. 28/10/08 (10.35 a.m.) 52° 34′ N.; 4° 45′ W. Depth of station, 43·9 metres.

Depth (metres)	T°	Cl °/oo	S °/oo	σ_t
0	13·6	19·18	34·65	26·02
10	13·5	19·15	34·60	26·00
20	13·5	—	—	—
42	13·5	19·16	34·61	26·02

Station X. 28/10/08 (11.45 a.m.) 52° 24′ N.; 4° 43′ W. Depth of station, 36·5 metres.

Depth (metres)	T°	Cl °/oo	S °/oo	σ_t
0	13·4	19·09	34·49	25·94
10	13·35	19·08	34·47	25·94
20	13·35	—	—	—
35	13·35	19·08	34·47	25·94

The results given in the preceding tables bear out in a most satisfactory manner the conclusions drawn from the first year and a half's work and given in last year's report. We again find:

(1) That in nearly all cases the water at any given spot has practically the same salinity from top to bottom. The only notable exceptions are the first two stations near Morecambe Bay, and, as shown in last year's report, the difference between top and bottom salinities in these cases is undoubtedly due to tidal effects. Even at the very deep stations investigated during the June trip there is only a very small increase in salinity with depth. The importance of this fact will be discussed presently.

(2) There is a well marked but small seasonal variation in the salinities. This point is clearly brought out by the table on page 160, which gives the salinities at the ten stations for the various months. Both top and bottom salinities are given in cases where there was any marked difference.

It will be seen that in the case of the first four stations the salinity is at a minimum about February and at a maximum about October, while the times of the maxima and minima are exactly reversed in the case of stations V, VI and VII. The maximum salinity at stations VIII, IX and X no doubt also occurs in October and the minimum in February, though unfortunately, owing to the bad weather, no samples could be collected from these stations during the February trip.

The cause of these seasonal variations is worthy of some consideration.

It is well known that the salinity of considerable areas of the North Sea and English Channel is influenced by the variation in the amount of warm Atlantic water of comparatively high salinity flowing into it (the so-called

Gulf Stream Drift). The amount of this is greatest in the spring and least in the autumn, so that the salinity at any spot in the North Sea affected by these changes is greatest in the spring and least in the autumn.

Position.	February, 1908.	May, 1908.	July, 1908.	October, 1908.
STATION I. 54° N.; 3° 30′ W.	32·66 32·72	32·3 32·6	32·8 33·2	32·39 33·35
STATION II. 54° N.; 3° 47′ W.	32·77 32·84	32·9 33·4	33·2 33·6	33·9
STATION III. 54° N.; 4° 4′ W.	33·1	33·6	33·95	34·1
STATION IV. 54° N.; 4° 20′ W.	33·3	33·95	34·0	34·0
STATION V. 53° 53′ N.; 4° 46′ W.	34·2	34·25	34·1	34·04
STATION VI. 53° 43′ N.; 4° 44′ W.	34·35	34·1	34·1	34·1
STATION VII. 53° 33′ N.; 4° 41′ W.	34·1	34·05	34·14	34·0
STATION VIII. 53° 5′ N.; 4° 44′ W.	—	34·4	34·4	34·6
STATION IX. 52° 34′ N.; 4° 45′ W.	—	34·3	34·3 34·5	34·6
STATION X. 52° 24′ N.; 4° 43′ W.	—	34·3	34·3	34·5

One object of the investigations, with which this report deals, was to see whether any such changes in salinity due to variations in the inflow of Atlantic water could be detected in our district.

Now, as we have seen, seasonal variations do occur in this district, but as already suggested in last year's report they are probably due in great measure to an entirely different cause, namely, variations in the amount of fresh water flowing in from the land.

The amount of this inflowing fresh water to the north-east of the line, Calf of Man Holyhead, is very large, and is probably greatest during the winter months. The tidal currents in this area are also very strong and cause very thorough mixing of the waters, and the occurrence of the minimum salinity about February, therefore, accords very well with the view expressed above. The same explanation will hold for the Carnarvon and Cardigan Bay Stations, though the amount of inflowing fresh water and consequent salinity variations, as also the tidal effects, are much less important. If the salinity variations of these stations were due to the Gulf Steam Drift the minimum should occur in the autumn and not in the spring, as it actually does. Now, at Stations V, VI, and VII the minimum salinity does occur in the autumn, and there can be no doubt that in these cases the variations are due to the Gulf Stream Drift. The variations are, it is true, only small, but that is not surprising, for these stations clearly mark the farthest points in the Irish Sea at which the effect of the Drift is detectable. At all stations affected by land water, as in Cardigan and Carnarvon Bays, and at all stations N.E. of the line Calf of Man Holyhead, the small effect due to the Gulf Stream Drift is entirely masked by the much larger effect due to the inflow of fresh water from the land.

In this connection it is of much interest to note that

Mr. Holt's figures* show that spring maxima of the salinities are only found at stations situated to the East of a line running W.S.W. from the Calf of Man to latitude 53° 38′ N. and thence approximately S.S.W. It is therefore permissible to conclude from our results, in conjunction with Mr. Holt's, that there is a narrow tongue of Gulf Stream water running up the centre of the Irish Sea, the effect of which on the salinity can be detected as far as a little to the East of the line Calf of Man—Holyhead. Owing to the fact that the tide from the South is stronger than that from the North, the water composing this tongue eventually passes right through the Irish Sea and out through the North Channel, but beyond the point mentioned its effects are masked. The salinity results, moreover, bring out another very important point, and that is that nearly all this water passes to the East of the Isle of Man, only a relatively unimportant part running round to the West of the Island. Of course, one already knew that this was probably the case from the general set of the tides in this area.

It must be remembered that the strength of the Gulf Stream Drift varies from year to year, so that its effect will be more marked in the Irish Sea in some years than in others. During 1906 and 1907, for example, it does not appear to have been quite so strong as in 1908, for in the former we only found maximum salinities in the spring at the two Stations V and VI, while in 1908 we have found spring maxima at the three Stations V, VI and VII.

It is worth noting that the course followed by the Gulf Stream Drift up the Irish Sea bears no relation to the deep channel which runs between Ireland and the Isle of Man and through the North Channel. As is well known, this deep channel is in reality a submerged river valley and does not owe its origin in any way to marine currents, which, therefore, need not be expected to pay much attention to it. The water filling this channel, even in the deepest parts of the Mull of Galloway, is wonderfully constant in composition, merely showing the small increase in salinity with depth which was to be expected.

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* Not yet published, but very kindly communicated to us.

A few words must now be said about the temperatures of the various soundings. Needless to say, these are higher in the summer than in the winter. In the majority of cases the temperature is practically constant from top to bottom, only the surface water being, as a rule, slightly warmer than the rest. Occasionally in some of the deeper stations there is a slight fall in temperature with depth, but our usual ten stations are not deep enough for this always to be observed. This fall of temperature was, however, well marked in the case of all the deep stations investigated during the June trip, though the difference between top and bottom temperatures only amounted to 0·7° at the deepest station (240 metres) and 2·5° at another station 100 metres in depth. The difference between top and bottom temperatures at the two shallow Stations I and II is often considerable, but this is chiefly due to tidal effects. The surface water is also often abnormally warm at other stations near the coast, for example, those in Cardigan Bay.

The question of the relation between the temperature at any spot and the distance from the land is discussed by Mr. Johnstone in a separate paper.

If the preceding tables are studied carefully it will be noticed that in a few cases instead of a gradual fall in temperature on going from top to bottom there is either a small intermediate rise or fall. This happens once at Station I (in October) and once at Station II (in February), when the water at ten metres is slightly colder than that at top or bottom. In May, at Station VII, the intermediate water is slightly cooler than that at top or bottom, while at Station VIII it is slightly warmer. The most striking case, however, is that of Station V in July, when the water at 30 metres is considerably colder than that at any other depth. Such variations are not at all surprising when one considers the way in which changes of temperature at the surface affect the temperature of the water below.

A rise of temperature at the surface will slowly be transmitted by conduction to the water at the bottom, the time it takes to reach the bottom depending upon the depth. A fall of temperature will, as a rule, be transmitted more quickly to the bottom, especially when, as in the Irish Sea, the water has almost the same salinity from top to bottom, for if the temperature of a layer of water falls its density increases and, if it becomes greater than that of the warmer water below it, it will sink. This process will continue with other layers, and so the cooling of the water proceeds from the top chiefly by means of convection currents, and far more rapidly than it would by mere conduction of heat. It is for this reason that one hardly ever finds that the temperature rises when going from the surface to the bottom, but that it nearly always falls.

Now, the changes of temperature require time to reach the bottom, so it is easy to understand that before the effect of a spell of warm weather has had time to get to the bottom the effect of a succeeding spell of cold weather may have begun to travel downwards, or *vice versa*. It is in this way that the above-mentioned intermediate warmer or cooler layers are to be explained. On referring to the tables it will be seen that in some cases these intermediate layers are clearly in unstable equilibrium, since the value for σ_t for a cooler layer is greater than the value for the underlying layers, while for a warmer intermediate layer it is less than the value for the overlying ones. This is well shown in the case of Station V in July. The differences of σ_t for Stations VII and VIII in May are within the limits of experimental error.

Similar cases of warmer or cooler intermediate layers were noticed in 1906 and 1907, but at quite different stations.

From what has been said above it will be readily seen that these irregularities are of a purely accidental nature, and it is necessary to point out most emphatically that their existence in rare cases in the Irish Sea has nothing whatever to do with currents of either cold or warm water between the surface and the bottom. Such currents certainly do not exist.

On the chart which accompanies this report the position of the isohaline lines has been indicated. All the observations made during 1906-1908 have been utilised in fixing the position of these lines, which, however, must only be considered as approximate, as the observations, except at the ten ordinary stations, are far too few. The positions of the various stations at which observations have been made are indicated by small circles. The chart is meant to refer to the month of June, when the isohalines may be regarded as being in a sort of mean position.

The extreme limit at which the Gulf Stream Drift can be detected is approximately indicated by the 34·0 isohaline on the chart.

In conclusion, the plans for the hydrographic work for the year 1909 are given.

Stations VIII, IX and X will be given up, as it is considered that as much information has been obtained from them as can be got.

Observations at Stations I to VII will be continued, and new ones started at three or four stations on lines connecting Piel Gas Buoy and Maughold Head and Calf of Man and the North West Light Ship. These new lines will be started, as it is desirable to have more information about the salinity of the areas of water they cross. The observations will be made every six weeks instead of every three months, so that the times of minimum and maximum salinity may be determined more exactly.

Determinations of salinity, except in special cases, will only be made on the surface and bottom water, and at the shallower stations only on the surface water, since the fact that the salinity in the Irish Sea is practically uniform from top to bottom makes further determinations unnecessary. Temperatures at intermediate depths will, however, be taken.

Description of Plate II.

Approximate positions of isohalines in the Irish Sea in June, 1906-8.

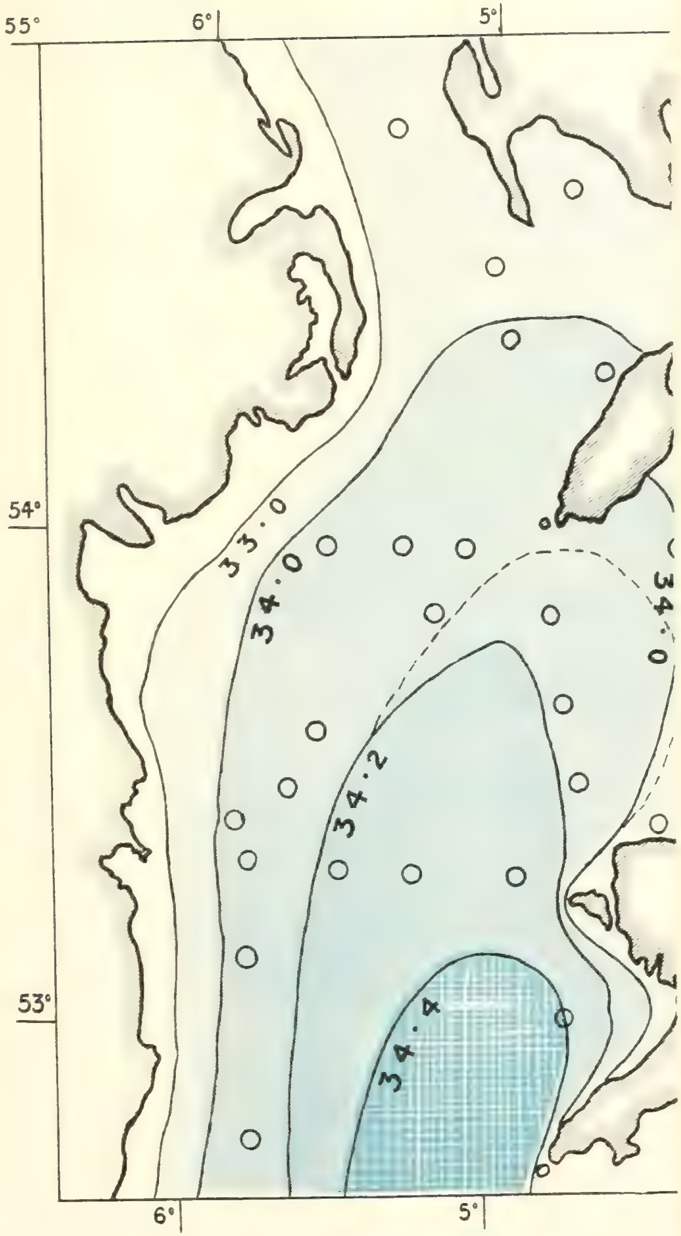
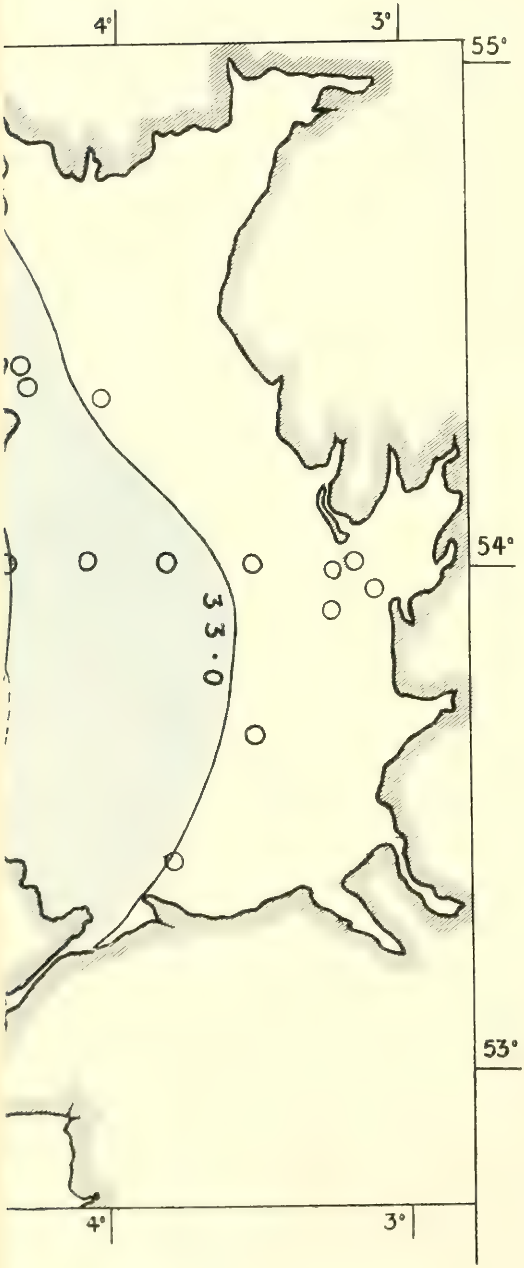

55°
6°
5°
54°
53°
6°
5°
33·0
34·0
34·2
34·4
34·0

Plate II.



REPORT ON TEMPERATURE OBSERVATIONS IN THE IRISH SEA DURING 1907-8.

By Jas. Johnstone.

In another paper in this Report Dr. Bassett discusses the results of the periodic hydrographic cruises carried out during the last year, and gives a series of tables recording the temperature observations made on those occasions. In addition to these data we are now in possession of other temperature records. These are:—(1) daily observations made on board some of the Light Ships stationed on the West coast of England and Wales; and (2) hourly observations made on board the "James Fletcher" by the officers of the vessel. I propose to summarise the results apparent from a consideration of these records.

Methods. The light-ship observations are made for the Meteorological Office, and copies have been supplied to the Lancashire and Western Sea-Fisheries Committee by the Director, Dr. Shaw. The readings are Fahrenheit ones, and have been converted to Centigrade values. The deep-sea temperatures of the periodic cruises have been taken by means of the Nansen deep-sea thermometer, used in the Nansen-Pettersson insulating water-bottle, a method which seems preferable to the use of reversing thermometers. Surface temperatures on the periodic cruises are taken by thermometers made by Richter, of Berlin. All these instruments are provided with Charlottenburg certificates. They are read to the nearest 0·05th of a degree. As a rule the correction is not applied, this being a needless refinement of method when the special conditions prevalent in the Irish Sea are considered. The temperatures taken on board the "James Fletcher" in the course of the ordinary patrol duties are read from "Kiel" thermometers, supplied by Küchler, of Ilmenau-in-Thuringia, and the readings are correct to the nearest 0·2° C.

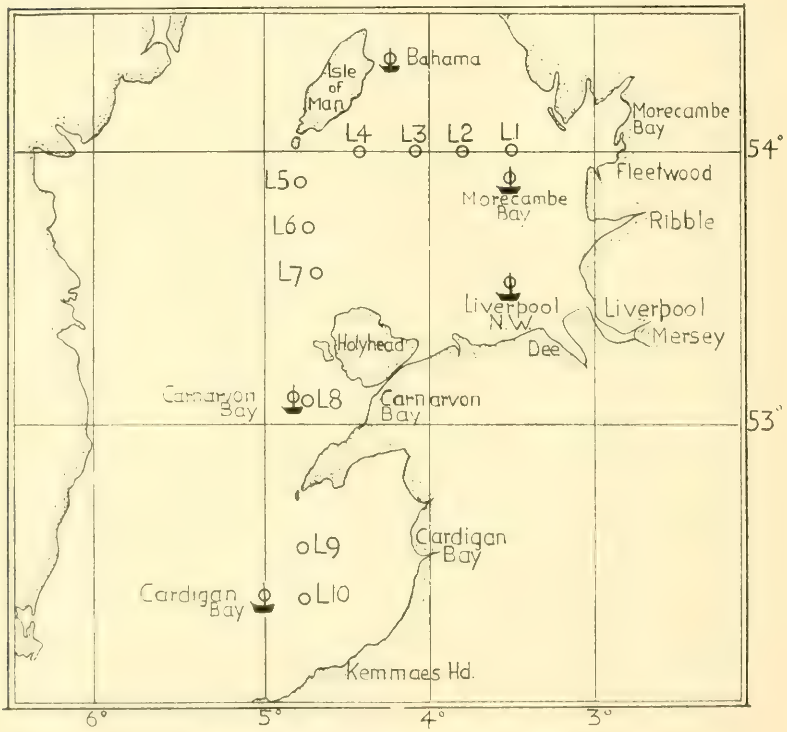


Fig. 4. Hydrographic Stations in 1907-8.

Light Ship records.

We may consider these, first of all, as giving the best general representation of the annual changes of temperature at different points on the West Coast. The sketch-chart above shows the approximate positions of these vessels, as well as those of the hydrographic Stations L1 to L10, investigated in 1907 and 1908. Table I is constructed from the daily temperature records supplied by the Meteorological Office. Only the readings at 4 p.m. are considered. Ten-daily averages throughout the year have been calculated. In the curves these are further smoothed by taking the averages of each three ten-daily periods. The values, therefore, represent thirty-daily averages, taken every ten days. In this way the minor fluctuations are eliminated, and the curves indicate the annual changes of sea temperature influenced by the larger variations peculiar to the year 1907.

[Table on next page.

TABLE I.

Sea temperatures (° Cent.) at certain Light Ships off the West Coast of England and Wales: Ten-daily Averages, 1907.

PERIOD.	CARDIGAN BAY: 52° 11' N. 5° 1' W.	CARNARVON BAY: 53° 6' N. 4° 45' W.	LIVERPOOL NORTH-WEST: 53° 31' N. 3° 31' W.	MORECAMBE BAY: 53° 54' N. 3° 31' W.	BAHAMA BANK: 54° 20' N. 4° 13' W.	SOLWAY: 54° 48' N. 3° 32' W.
Jan. 1-10 ...	9·25	8·4	5·75	6·25	6·85	4·75
„ 11-20	9·05	8·45	6·2	5·9	6·95	5·8
„ 21-30	8·0	7·4	5·1	4·35	5·9	3·6
„ 31-Feb. 9 ...	7·6	7·3	4·45	4·6	5·65	2·85
Feb. 10-19	7·2	7·15	4·6	5·25	5·95	3·15
„ 20-Mar. 1 ...	7·15	6·8	4·3	6·1	5·15	3·65
Mar. 2-11	7·65	6·85	4·8	7·25	5·55	5·05
„ 12-21	7·75	6·85	5·85	7·85	6·05	5·25
„ 22-31	8·0	7·3	7·85	9·0	7·0	7·65
April 1-10	7·95	7·4	7·05	9·1	7·25	7·6
„ 11-20... ...	8·0	7·55	7·175	7·85	7·2	6·95
„ 21-30... ...	8·45	7·85	8·1	7-85	8·25	8·85
May 1-10	8·65	8·4	8·65	9·05	8·25	8·85
„ 11-20	8·85	8·85	9·65	11·05	9·6	10·5
„ 21-30	11·35	9·5	11·25	11·0	10·35	10·7
„ 31-June 9 ...	10·65	9·65	10·9	10·55	10·1	10·95
June 10-19 ...	11·5	10·35	11·65	12·85	11·05	12·7
„ 20-29 ...	11·45	10·85	no observations	13·05	11·6	12·45
„ 30-July 9 ...	12·4	11·6	12·6	14·35	12·35	13·1
July 10-19	13·45	12·1	14·45	15·6	13·85	14·85
„ 20-29	14·25	12·7	14·35	17·95	14·95	16·35
„ 30-Aug. 8 ...	14·25	12·55	15·1	16·7	13·85	15·35
Aug. 9-18	16·65	12·65	14·75	16·8	14·15	15·15
„ 19-28	16·8	13·5	15·4	15·2	14·0	14·4
„ 29-Sept. 7 ...	16·95	13·5	14·85	14·65	14·05	13·75
Sept. 8-17	17·5	14·0	14·55	15·0	14·7	14·2
„ 18-27	17·45	14·1	14·55	15·35	14·85	14·35
„ 28-Oct. 7 ...	17·05	13·75	13·65	14·65	14·25	13·6
Oct. 8-17	16·45	13·2	12·7	13·05	13·2	12·0
„ 18-27	14·45	12·6	12·75	12·1	12·6	10·9
„ 28-Nov. 6 ...	12·45	12·6	11·85	11·65	12·1	10·0
Nov. 7-16	12·15	12·25	11·15	10·75	11·15	9·35
„ 17-26	11·6	11·55	9·45	9·3	9·75	7·85
Nov. 27-Dec. 6 ...	11·0	11·4	9·1	8·15	9·1	6·6
Dec. 7-16	10·55	10·25	8·65	7·1	8·65	6·35
„ 17-26	10·25	9·95	8·05	6·55	8·35	6·35
„ 27-31	9·2	8·9	6·2	5·9	8·0	5·0

The values in Table I are average ones, and Table II gives the lowest and highest temperatures actually observed.

TABLE II.

Annual maximum and minimum sea temperatures at various West Coast Light Ships.

Light Ship.	Maximum Temperature.	Minimum Temperature.	Annual Range.
Cardigan Bay ...	19·4°C., 23/9/07	5·5°C., 12/2/07	13·9°C.
Carnarvon Bay ...	13·9°C.,18-20/9/07	6·7°C.,21-24/3/07	7·2°C.
Liverpool North-West	18·9°C., 2/8/07	1·7°C., 3/2/07	17·2°C.
Morecambe Bay ...	19·4°C., 21/7/07	3·3°C., 30/1-7/2/07	16·1°C.
Bahama Bank ...	17·2°C., 21/7/07	4·4°C., 22-24/2/07	12·8°C.
Solway	18·3°C., 21/7/07	1·1°C., 31/1/07	17·2°C.

The annual temperature changes are further represented in the series of charts, figs. 5 to 10 on pp. 172 and 173.

Considering these, along with Table II, one sees at once that there are notable differences at the various Light Ship stations. The greatest extremes of temperature were observed in 1907 at the Liverpool North-west Vessel, and in the Solway, both of which stations are fairly near the land, and under the influence of the latter. The least annual temperature change was observed at the Carnarvon Bay Light Ship. The water at this point appears to possess a more truly "open-sea" character than at any of the other stations investigated by us in the Irish Sea. The maximum temperatures of the year were attained at the Cardigan Bay and Morecambe Bay Light Ships; at the former station because of its more southerly position, and at the latter because of the influence of the Morecambe Bay sandbanks. The lowest Irish Sea temperatures were experienced at the Liverpool North-west Light Ship. The minimum in the case of

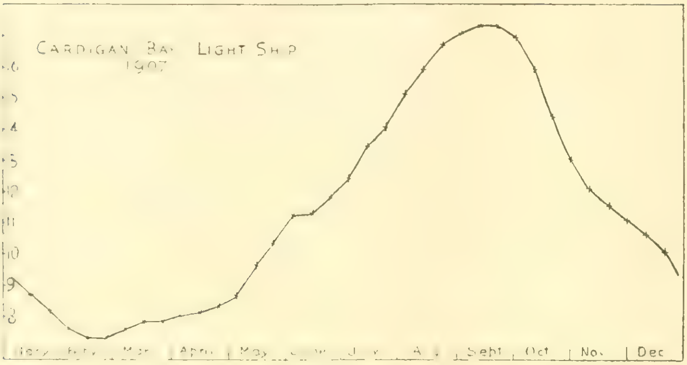


Fig. 5.

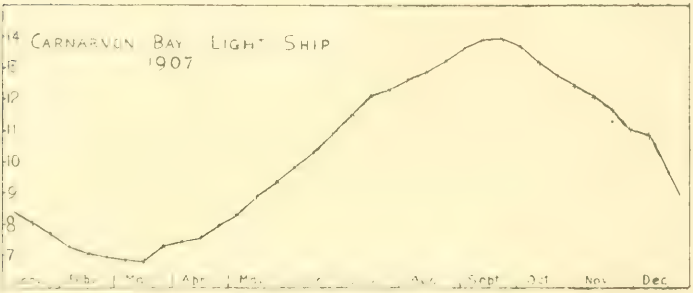


Fig. 6.

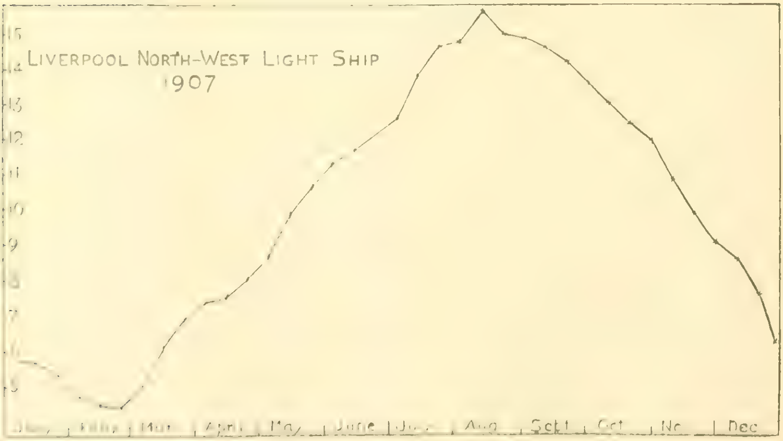


Fig. 7.

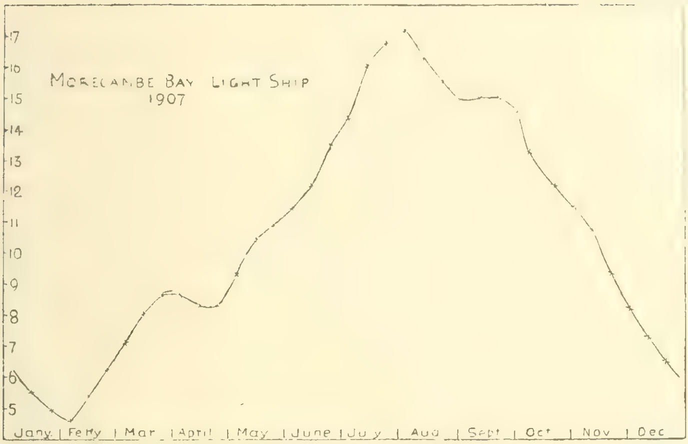


FIG. 8

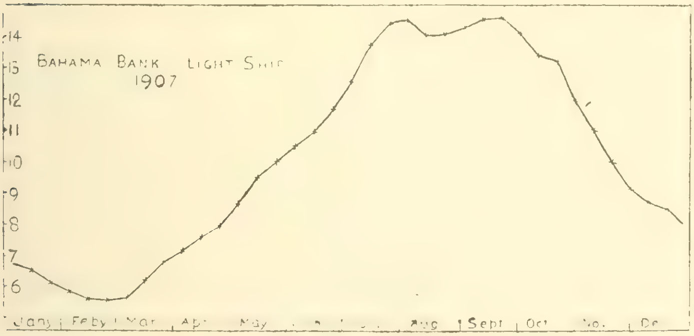


FIG. 9.

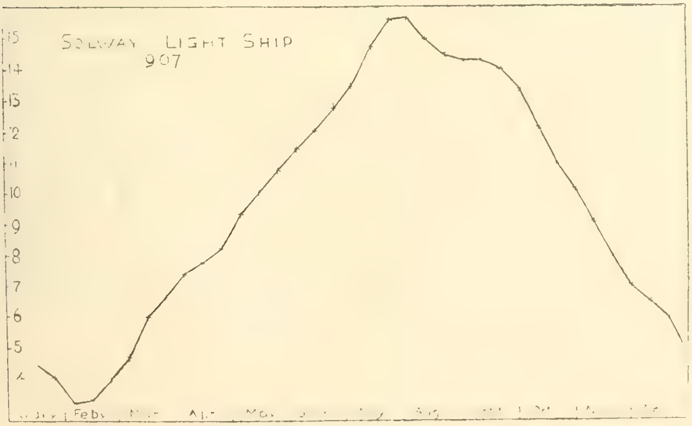


FIG. 10.

the Solway is lower still, because of its more northerly situation. The temperature of the sea at both of these stations is greatly influenced by the excessive rainfall of the land adjacent to them.

The date of the minimal temperatures is very much the same at the various stations, occurring during February, except in the case of the Carnarvon Bay station, where the minimum occurred in March. The dates of the occurrence of the maximal temperature vary a little more, occurring in September in Cardigan and Carnarvon Bays, and a little earlier at the other stations. There is no doubt, of course, that the rise of temperature culminates at a slightly different time of the year in each case, but several years' records will be required before this can be exactly determined.

Irregularities in all the curves, due to the weather changes experienced in 1907, are to be observed. It is worthy of note that these changes were much smaller at the Carnarvon Bay station than in any of the others, indicating that the water offshore from this Bay is less affected by the heating or cooling action of the land than at any point in the Irish Sea, or in the immediate neighbourhood of the Isle of Man. They are greatest in the case of the sea near the Morecambe Bay vessel, which is influenced by the adjacent land to a quite remarkable degree.

Minor Temperature variations.

Apart altogether from the annual temperature wave, and the smaller ones superposed upon it, as the results of weather variations, there are still smaller changes of temperature due to other causes. If the daily temperatures at any one of the Light Ship Stations be plotted a curve will be obtained which is remarkably "jumpy."

"zig-zaging" up and down in quite a violent manner. This will be seen on consulting figs. 11 and 12, which show these smaller temperature variations at the Morecambe Bay Light Ship. Three-daily averages have been calculated for every day during the first six months of 1907—that is, the temperature record for each day is allowed to be influenced by those of the preceding and succeeding days. If the actual daily temperatures were plotted the changes would be still more violent. Then the curve obtained by plotting thirty-daily averages every ten days is superposed on this three-daily curve. In the figures this latter curve is represented by the horizontal straight line, and the three-daily temperatures are shown as variations above and below what may be regarded as the mean for the whole period considered.

Now, it will be seen that during the months January to March, inclusive, the sea temperature fell at intervals about 0·5° C. to about 1·5° C. below the mean, and rose, on the average, about 0·5° to 0·75° C. above the mean. Further, during the months April to June, inclusive, the temperature varied between about 1·5° C. below, and 3·0° C. above the mean. Similar variations are observed when we consider the third quarter of the year, and there are smaller variations during the fourth quarter.

It is inconceivable that these smaller variations can be due to variations in the amount of heat directly transmitted to the sea by varying solar radiation, or by heat yielded up to the surface layers by contact with warmer or colder wind currents, or by differences in the amount of evaporation occasioned by atmospheric changes. The specific heat of sea-water is so great that enormous quantities of heat would have to be exchanged between sea and atmosphere in order to account for a variation of 3° C. in the period of a few days. It is, of course,

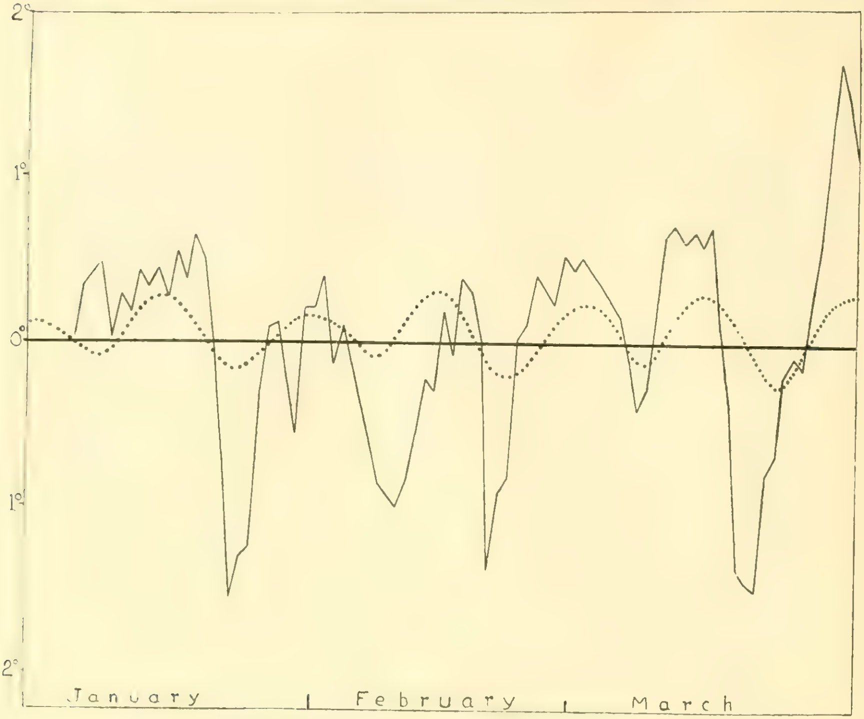


Fig. 11.—Periodicity of temperature variations.

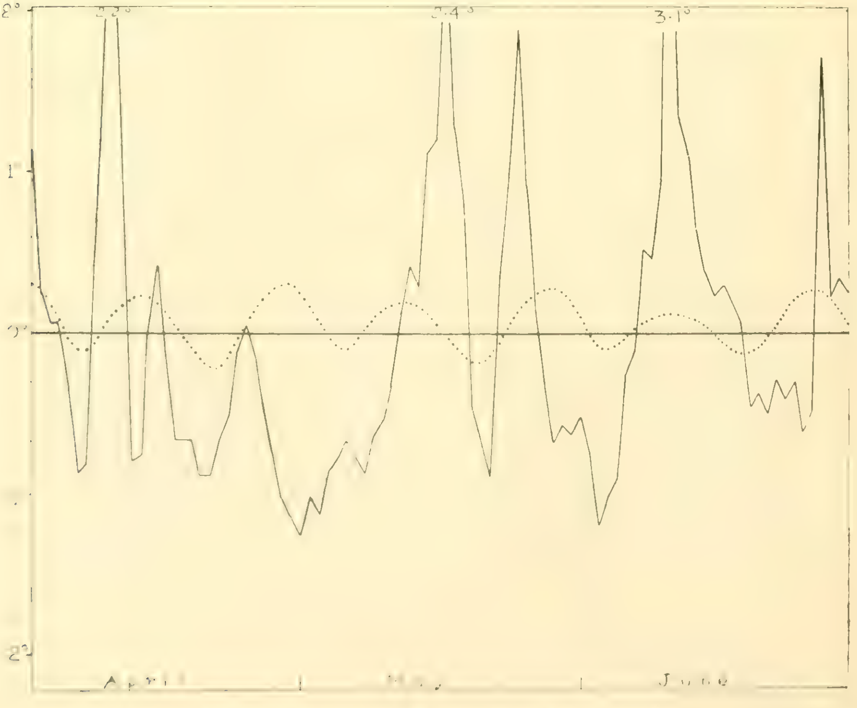


Fig. 12.—Periodicity of temperature variations.

obvious that a warm wind (S. to W.) blowing steadily for a day or two must warm the surface of the sea, and, conversely, that a cold wind (N.W., N., N.E., or E.) would also chill the surface water. But the wind would only affect an exceedingly thin superficial layer of sea-water, and this would be drifted along in the direction towards which the wind was blowing. In a tideless water-basin. such as a lake, the effect of this would be that warmer or colder water would be piled up along the coast towards which the wind was blowing while a deep counter-current, flowing in the opposite direction, would be set up. In this way the well-known stratification observed in enclosed lakes and in some sea lochs on the West Coast of Scotland, is produced. The same effects ought to be produced in the Irish Sea, but, as a matter of fact, the temperature stratification is not observed; and the effect of a spell of cold or warm wind is simply to produce a homothermic water mass. Our experience in studying the temperature of the sea seems to be that the latter varies according to the prevalent wind. Yet when we try to express this relationship, by comparing curves showing the direction of the winds, and the temperature variations, from day to day, no correspondence between the two series of changes can be detected.

But, when we compare the small temperature changes with tidal changes, a direct relationship is at once apparent. The Eastern part of the Irish Sea is a shallow-water basin, and one may say that all the water within the twenty-fathom line, that is Liverpool Bay and practically all the sea lying between the Isle of Man and the Lancashire and Cumberland coasts, and the sea within an average distance of 6½ miles to the West, and 3½ miles to the South of the Isle of Man, is coastal water. All along the West Coast of England, between Anglesey and the

Solway, are extensive sandbanks which are twice in every twenty-four hours exposed to the atmosphere. For instance nearly 100 square nautical miles of sand are exposed twice a day in the Morecambe Bay area. There are also high tides, with a rise and fall of over thirty feet in some places and tidal streams with a velocity of seven knots at high springs. In the fairway of the Channel the backward and forward surge of water due to the tides is about nine miles during springs, and about six miles during neaps. Near the land the distance traversed by the moving body of water greatly increases.

When the sandbanks are exposed by ebb-tide during the winter and spring months they become cooled greatly by radiation and evaporation; and when next the flood water covers them the latter becomes chilled below its normal temperature. Further, when the sandbanks are exposed during the summer and autumn months they are heated, and when next the flood-tide covers them the water becomes warmed above its normal. Therefore, the sea offshore at any one point is alternately warmer and colder as these water masses are carried backward and forward by the tides. If we could take daily temperature observations out from the mouth of Morecambe Bay, as, for instance, at Piel Gas Buoy, it would be found that the temperature would generally be lower during the flood-stream, and warmer during the ebb-stream, in the summer months, while an exactly opposite condition would be experienced during the winter and early spring.

The effect of changes in the height of the tides would also be apparent, for the extent of sandbanks covered, and consequently the amount of heat received or lost by the flood water, would vary from neaps to springs; and since the velocity of the streams also varies during a tidal cycle the alternating masses of colder or warmer water would be carried to a varying distance from the land. I think that the curves in figs. 11 and 12 show this effect of the tides very clearly. The dotted line represents the height of the tide at Liverpool from day to day—it indicates springs and neaps. Now, in these the fortnightly periodicity of temperature change in the sea-water is very plainly seen. For about a week, speaking roughly, the temperature of the sea at Morecambe Bay Light Ship falls below the mean, and during the succeeding week it rises above the mean. That is, the smaller temperature variations are to be associated with the fortnightly rise and fall in the height of the tides. Of course, the correspondence of the two series of changes is not very exact: one can hardly expect it to be since the surface drift of water due to high winds must have a certain influence, and the phases of the curves do not always coincide. But I think it is clear that the main cause of the smaller temperature variations in the sea off the West Coast of England is the transport of water masses of different temperature by the tidal streams.

This conclusion is supported by the study of the isotherms in the Irish Sea. At the present time we do not possess sufficient data to enable these to be drawn for different periods of the year, and I only give one chart, fig. 13, which shows the positions of these lines for the beginning of August, 1908—the local period of maximum temperature of the sea. It will be seen that they do not run parallel to the coast as might at first be expected, but rather roughly parallel to the twenty-fathom contour-line of sea depth. Outside this contour-line the water is influenced to a much less extent by the land, than within it. The 14° isothermal-line curves round East from the Skerries at Holyhead parallel to the coast of Anglesey, then turns to the West again about halfway between the coasts of Lancashire and the Isle of Man, and approaches the latter near Castletown. Near the land the water is much warmer than offshore. During the period of minimum temperature (February) the direction of the isotherms is very much the same, but the change of temperature is then completely reversed—that is, the water

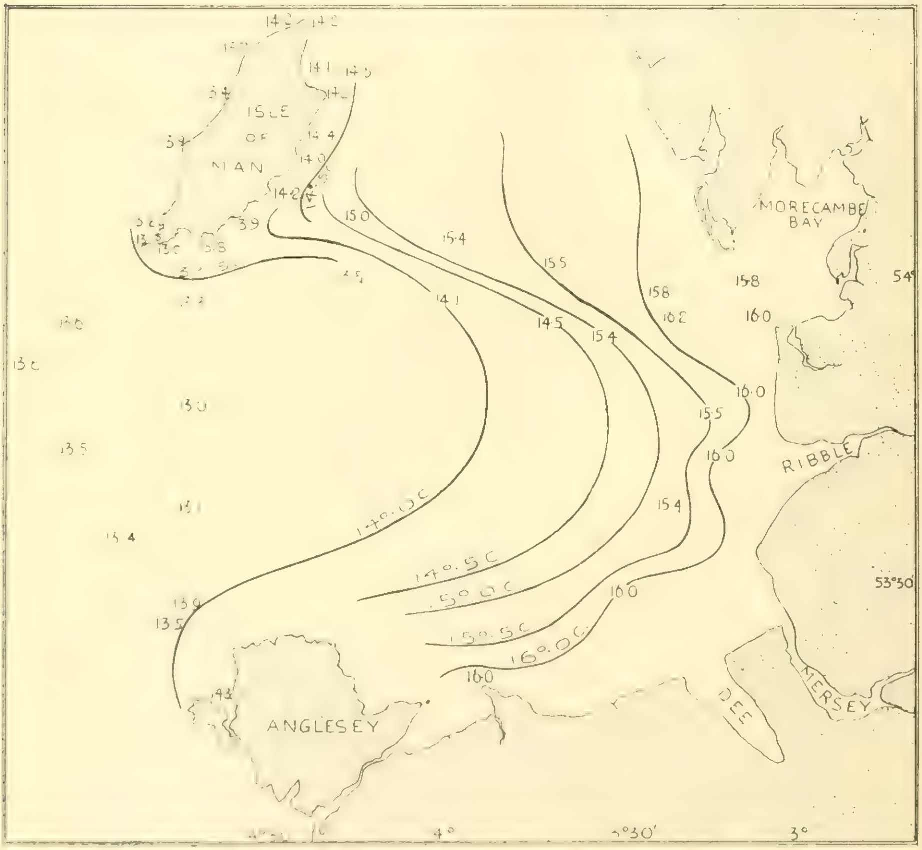


Fig. 13. Probable isotherms in the Irish Sea in August, 1908.

offshore is much warmer than the water inshore, so that the 7°-8° isotherm occupies roughly the same position in February as the 14°-15° line does in the summer. In August the 16° isotherm runs close to, and parallel with, the English coast: while in February the 3°-4° line occupies much the same position.

The cause of this peculiar distribution of temperature is the direction of the tidal streams in the eastern part of the Irish Sea. The South tidal wave runs up St. George's Channel and bending round Anglesey, according to "Ferrel's Law," turns to the East into Liverpool Bay. The North tidal wave sweeps down the North Channel and splits on Point of Ayre, and the major portion of the stream runs between Isle of Man and Cumberland: a much less rapid tide runs along the West side of the Isle of Man, the North and South streams meeting about Contrary Head, while out between the Calf and Loch Carlingford in Ireland, the streams are hardly perceptible. On the English side the two tidal streams interfere between Morecambe Bay and Maughold Head, in the Isle of Man. Therefore, the whole sea area between the coast of North Lancashire and the Isle of Man is affected by the tidal water surging into and out from Morecambe Bay. It is heated in the summer and cooled in the winter, by the powerful influence of the latter extensive tract of shallow water.

The Vertical Distribution of Temperature.

The data for the study of the vertical distribution of temperature are included in the tables contained in the reports by Dr. Bassett,* on the hydrographic observations. The temperatures recorded as the results of well over 120 hydrographic soundings, make the conclusion inevitable that the Irish Sea is a practically homothermic water mass, and that the small differences indicated by the soundings are purely "accidental," in the sense that they have nothing whatever to do with a real temperature stratification, nor are they indicative of the existence of deep water currents. The results of the observations of 1907-8 are tabulated as follows:—

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* *Annual Report Lancashire Sea Fisheries Laboratory*, for 1907, Liverpool, 1908, pp. 54-79; and pp. 44-64 of the present Report.

Station.		Mean Depth. Metres.	Mean Difference Surface and Bottom Temperatures. °C.	Maximum Difference. °C.	Minimum Difference. °C.
Piel to Calf of Man	I	27·5	2·45	3·8	0·1
	II	37·5	0·70	1·3	0·1
	III	36·5	0·32	0·6	0·15
	IV	40·5	0·17	0·3	0·05
Calf of Man to Holyhead	V	72·5	1·14	2·23	0·05
	VI	57·5	0·4	0·7	0·1
	VII	57·5	0·22	0·35	0·1
Welsh Bays	VIII	65	0·42	0·75	0·1
	IX	39·5	0·6	1·1	0·1
	X	38·5	0·62	1·2	0·05

Now, considering these figures, we see that the greatest difference in temperature between superficial and deep layers is to be found, not in the deep water, but in the shallow water near the land. Thus the mean difference is greatest 2·45° C. at Station I, which is about ten miles from the coast, and is the shallowest of all. Then the difference between surface and bottom gradually decreases until Station IV, which is nearest to the Isle of Man, is reached. On the line between Calf of Man and Holyhead, the difference is greatest at the deep station near the Calf and decreases towards the South as the sea bottom rises. This line crosses the drifting water passing up the Irish Sea, and it is here, if anywhere that indications of a deep current, or stratum of different characters from those of the surface, might be expected. But the difference is due only to the cooling of surface water and the sinking, by convection, of this to the bottom.

All these stations, however, are comparatively shallow ones, and it might, perhaps, be expected that vertical differences of temperatures would be observed at places where the sea is deeper. Nevertheless, the observations made by the Irish Department of Agriculture and Technical Instruction (which have kindly been communicated to us by Mr. E. W. L. Holt) show that the temperature differences on the western side of the Irish Sea, and over the deep channel between Isle of Man and Ireland are similar to those found between Isle of Man and Holyhead. The results of a special hydrographic cruise made by us in this area, and in the deep water off the Galloway coast, in June, 1908, are quoted by Dr. Bassett in the preceding paper. Two soundings were made on this occasion in the deepest part of the sea round the British Isles, 248 to 267 metres. The temperature* at a mean depth of 230 metres was 8·97° C., and at the surface 9·82° C., a difference of only 0·85° C. Here the tidal streams are very rapid. A sounding taken near the middle of the sea-area bounded by the Galloway land, Ireland and the

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* Mean of two soundings made at opposite extremities of the gutter of deep water.

Isle of Man, showed a difference between surface and bottom of 2·25° C. Here the tidal stream is slight, or barely perceptible.

Summarising the results of these hydrographic soundings, we find the following conditions:—

1. Coldest at the bottom:
    60 cases (mean differences in Table IV);
2. Warmest at the bottom:
    3 cases: mean difference, 0·125° C.
3. Intermediate cold stratum:
    7 cases: mean difference, 0·175° C.;
4. Intermediate warm stratum:
    3 cases: mean difference, 0·125° C.;
5. Water absolutely homothermic:
    3 cases.

All these figures show that the Irish Sea is a practically homothermic water mass. The slight vertical differences of temperature can be traced to causes such as those indicated by Dr. Bassett in the preceding paper in this Report.

Some Conclusions.

So far as hydrographic investigation is concerned, the Irish Sea presents problems of a similar nature to those encountered elsewhere in the British area. It is, for instance, certain that here, just as in the case of the North Sea and English Channel, the annual influx of relatively high-salinity water, due to the variation in strength of the Gulf Stream Drift, can be detected. But, there are also special conditions and problems. The Irish Sea is a comparatively small sea area, and the extent of coast-line, and, therefore, the amount of land drainage, is relatively greater than in the case of the North Sea. It is shallow and characterised by high and strong tides; and, as a result of these conditions, there is a greater dilution of the sea-water, due to the influence of the land, than over the greater part of the North Sea: also there is a much more thorough mixture of the water of different regions than we find in the latter sea. Therefore, it is not to be expected that such sharply-bounded isohaline areas, or such positive indications of a flooding by water from without, as are observed in the North Sea* will be found in our area. Neither are seasonal changes in the positions of the isohalines, at least those delimiting water areas of the lower degrees of salinity, so sharply marked. There is no indication, none at least so far, of the existence of a more or less permanent layer of cold bottom water.† This is just barely indicated by the temperature differences at Station V. There are no indications of the inflow of cold bottom water from the sea North of the British Islands, for though the channel between Galloway and Ireland is relatively deep, the sea bottom between Islay and Ireland is shallow, forming a "barrier," while the depth of water at the opening to St. George's Channel is such as to admit only of the entrance of surface Atlantic water. It has been estimated‡ that the flow outwards through the North Channel is such that a water-particle will travel from the Irish Sea to the Scotland-Shetland Channel in about eighty days; at which rate the water-volume leaving the Irish Sea annually is at least equal to the entire volume of that sea, that is, 3,000 cubic kilometres. The planktonic fauna and flora of our area is, therefore, affected, not by the Sub-Arctic region, but by that of the Atlantic or Biscay latitudes, a conclusion which seems to me to be supported by the study of the fish migrations.

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* See D'Arcy Thompson, *Nature*, Dec. 17, 1908.

† Such as is known to exist in the North-Western part of the North Sea. Cf. Second Report *Fishy. and Hydrogr. Invests. in the North Sea and Adjacent Waters*, Pl. I [Cd. 3358], 1907, p. 11.

‡ Knudsen, *Publications de Circonstance. Cons. Perm. Internat. Explor. Mer*, No. 39. Copenhague, 1907.

On the other hand, we have to deal with a water basin in which seasonal salinity changes are relatively insignificant, and are dependent almost entirely on the amount of land drainage; in which tidal streams are so strong that they lead to an intense mixing up of the water. The latter is very uniform in composition, except within the twenty-fathom line, which may be regarded as the true coastal limit. Temperature changes are rapid and well-marked, and the positions of the isotherms depend, to a great extent, upon the course of the tidal streams. Apart from tidal streams there is only one "current," and that is the general drift of water from South to North.

Probably fish migrations are determined almost entirely by the temperature of the water, that is, they are to be associated with the shifting of the isotherms. It is quite likely that in the close study of the latter, combined, of course, with the study of the regional distribution of salinity, is to be sought the proximate causes of those fish migrations which lead to the establishment of "fishery periods." The latter are well marked in the Irish Sea: the summer mackerel and bass invasions; the winter cod fishery; the winter plaice fishery on the shoal grounds between Isle of Man and Cumberland; the summer plaice fishery in Liverpool Bay between Morecambe Bay and Liverpool North-west Light Ships; the Liverpool Bay sole fishery in the summer and autumn; and the "back-end" plaice fishery between Liverpool North-west Light Ship and the coast of Anglesey, are instances. It ought to be possible to associate these periodic fisheries with the changes in the isotherms, perhaps, also with the distribution of salinity. At any rate the extension of the hydrographic observations at present carried out, together with the most valuable information which will be afforded by the extensive series of observations now being made by the Irish Department of Agriculture and Technical Instruction, should enable us thoroughly to understand the physical conditions of the Irish Sea basin. Unfortunately, reliable fishery statistics, the collection of which is in other hands, are much more difficult to obtain.

We have seen that the minor temperature changes are set up by the translocation of masses of water of different temperature. Because of the strong tidal streams the precise delimitation of isothermal water areas in the Irish Sea is rendered most difficult. If it were possible to make very numerous simultaneous temperature observations over the eastern half of the Irish Sea we should certainly find scattered " islands " of cold or warm water here and there over the inshore region. Obviously, the small, rapidly occurring temperature variations, such as those indicated in figs. 11 and 12, are not occasioned by the heating or cooling of the sea *in situ*, but are due to the transference of comparatively large volumes of water from place to place.

There can be no doubt that the irregular distribution of the plankton of the Irish Sea, within the twenty-fathom contour-line, is to be traced to these movements of masses of water. This must obviously be the case with regard to those planktonic organisms which are pelagic stages of demersal animals: crab and sea urchin larvae, for instance, which are produced at one place and carried elsewhere by the movement of the water. Truly planktonic organisms, such as diatoms and copepods, especially such neritic forms as are indigenous to the Irish Sea area, probably segregate themselves in bands or zones of relatively great area—*Noctiluca*, for instance—and these zones probably coincide roughly with isothermal or isohaline regions, or with compromises of both factors. Indeed, it is even now possible to indicate these zones roughly. But, because of the irregular movement of the sea water, "islands" of plankton must be shifted from place to place, just as the temperature changes from place to place for the same reason. It will generally be practicably impossible so to control plankton fishing experiments as always to fish in water of the same origin. This must be the case in coastal waters (within the twenty-fathom line). Outside this limit the conditions are doubtless more uniform.

It does not follow that there are no vertical movements of the plankton because no well-marked thermal stratification of the sea is to be observed. Vertical planktonic migrations are probably set up both by changes in the intensity of light, and by convection currents, and the slight vertical changes of sea temperature are caused by the latter. Such irregularity of the plankton can be eliminated by making all hauls strictly vertical ones, from bottom to surface. But, so to control plankton fishing that the results of hauls may be quantitatively compared with each other, appears to me to be practically impossible, because of the complexity of the conditions characterising the coastal regions of the Irish Sea. It is, indeed, possible that there may be an approximate uniformity of the plankton in the central area South from the Calf of Man, and West from meridian 4° W., or in the fairway of St. George's Channel. But within the twenty-fathom line, the hydrographic conditions are so complex that the results of plankton experiments must be exceedingly difficult to interpret.

INTERNAL PARASITES AND DISEASED CONDITIONS OF FISHES.

By JAS. JOHNSTONE.

Dibothrium crassiceps, Rudolphi.

When trawling to the South-west of the Calf of Man in June, 1908, a small hake was caught which contained, in its intestine, about a dozen Cestodes, which I refer to the above species. The measurements of this worm are:

Total length of the strobilae: 50 to 60 mm.
Greatest breadth of the proglottides: 3 mm.
Greatest length of posterior proglottides: 1 mm.
Diameters of the scolex: 1·7 × 1·7 mm.

The anterior part of one of these worms is represented in fig. 14, and it will be seen that the scolex is spherical.

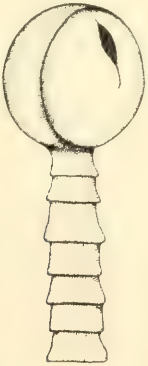
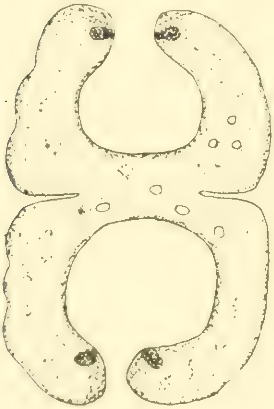
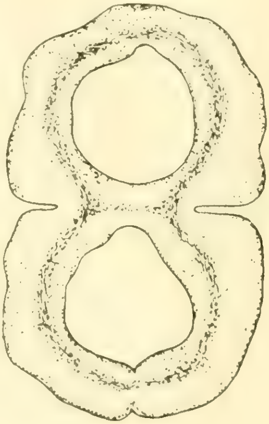


FIG. 14. *Dibothrium crassiceps*, Rudolphi. Mag. 11 dias.

A prominent groove divides it longitudinally into two sectional lobes, and in each lobe there is a bothrium. The latter presents itself externally as a longitudinal slit, widest at the middle, and diminishing to a mere chink at its anterior and posterior extremities. It is situated rather nearer to the anterior end of the scolex.

This slit is the opening of a deep and rather large cavity. Fig. 15 represents a transverse section of the scolex made directly through the widest part of the opening of the bothrium. Within this is a large cavity, which in the unpreserved specimen is probably nearly hemispherical in shape. The darkly dotted areas at the sides of the openings of the bothria probably represent bundles of muscular and fibrous tissue, serving for the contraction of these openings. The irregular spaces represented in the figure within the walls of the bothria are probably the sections of excretory channels. Fig. 16 represents a section made through the scolex some distance behind the opening of the bothrium. Here also a number of fibres are seen running irregularly, probably obliquely, round in the walls of the bothrium. These no doubt function as constrictors of the latter. The cavity extends throughout almost all the length of the scolex.





Dibothrium crassiceps. Mag. 33 dias.

Fig. 15. Trans. section of scolex through opening of bothrium.

Fig. 16. Similar section posterior to that shewn in Fig. 15.

The proglottides are not figured. There is no distinct neck in the worm, and the segmentation begins immediately behind the scolex. The posterior proglottides are much broader (in the transverse axis of the strobila) than they are long (in the longitudinal axis of the strobila), and their anterior extremities are narrower than the posterior ones, so that the edge of the strobila appears to be serrated. Secondary segmentation of the proglottis often occurs. According to Linton,* the "cuticle is covered with minute spines," but I can see nothing of this kind in the specimens before me. The genital openings are in the middle line of the proglottides, but near the anterior borders of the latter.

Zoogonoides viviparus (Olsson).

A large plaice caught in Luce Bay in October, 1908, died shortly after it had been put into the tanks at Piel. It was 58 cms. in length, and was 13 or 14 years of age. On dissecting it, about a dozen Trematodes were found in the hind-gut, quite near to the anus. They were pale yellow in colour when alive, very small, and just visible on close examination without a lens. The measurements were:—

Length: 1·03 mm.
Breadth: 0·33 mm.
Transverse diameter of oral sucker: 0·12 mm.
,, ,, ventral sucker: 0·19 mm.

There was very little variation in size.

The worm is not figured here. The skin of the part of the body in front of the ventral sucker was covered with short straight spines. There is a very small pharynx and no very conspicuous oesophagus. The intestinal rami go back as far as the ventral sucker. The testes are two round or ovoid bodies, situated one on each side of the ventral sucker, and in almost the same transverse plane, so that in a side view one hides the other. The ovary lies immediately behind the ventral sucker. The region of the body behind the ventral sucker is almost entirely occupied by the capsules containing the embryos, but there is a very large excretory vesicle at the posterior extremity. The vitellaria appear to lie immediately round and mostly in front of the ventral sucker.

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* "Parasites of fishes in the Woods Holl region." *Bull. U.S. Fish Commission*, Vol. XIX, p. 473, Washington, 1899 (1901).

The vesicula seminalis and cirrus lie immediately in front of the ventral sucker, and the genital opening is situated well towards one side. In most of my specimens the cirrus was protruded, and appeared to be armed at its tip by a loosely arranged bundle of short straight spines.

A Hake with degenerated parasites in the muscles.

In April last a piece of flesh from a hake, caught on the West coast of Ireland, and landed at Fleetwood, was sent to the Piel Laboratory. Mr. Driver, the Fish Inspector for Bradford, who sent the piece of flesh, informed us that it was a fair sample of a hake which had been condemned as human food. The muscles of the fish were permeated by small, dense black particles arranged in rows. Usually there were two or three of these particles in a row, but occasionally there were more. As a rule the rows were parallel to the general direction of the muscle bundles, but occasionally they ran athwart the latter. Further than this they showed no arrangement. Dissected out from the muscle tissue, and examined under the microscope, the little black particles showed no structure, and were almost perfectly opaque.

Fig. 2, Pl. III, represents the appearance of a small piece of the tissues of this fish stained with borax-carmine, cleared, and mounted in balsam. The black particles are seen to be round or oval egg-shaped structures, and they consist apparently of concentric shells of some structureless substance arranged round a nucleus. They may be compared with pearl-like concretions. Each of them, or sometimes two together, are surrounded by a kind of capsule, and the row, six in this case, is surrounded by a loose connective tissue. The whole lies between the muscle fibres, which have been forced apart.

Fig. 3, Pl. III, represents part of a section, made transversely to the muscle bundles, and stained with Mann's methyl-blue-eosin. It shows one of the black particles cut nearly through the centre, and lying among a group of muscle fibres. These bodies vary much in size and shape. Generally their diameters range from 0·39 × 0·15 mm. to 0·28 × 0·22 mm. They are usually egg-shaped. It is seen that each consists of a nucleus which has no definite structure, being composed entirely of granules, large and small, with sometimes masses of pigment, and sometimes highly refringent larger granules. Surrounding this nucleus are a variable number of concentric shells, made up of a substance showing no regular structure. These shells are occasionally rather widely separated, and the spaces between them often contain finely granular matter. Outside this highly pigmented concretion is a shell of fibrous tissue, apparently belonging to the intrusive body; and outside this again is another looser shell of fibrous tissue, looser in structure, and consisting of fine wavy bundles. In fig. 2 these are seen end on. Scattered among them are small nuclei. This part evidently belongs to the tissues of the host, and is an investment, protective it may be, and probably produced as the result of local inflammation.

The whole lies loosely among the muscle fibres, which are represented in section round it.

It is, of course, impossible to say what is the precise nature of these intrusive bodies. But it is highly probable that they are the eggs of some internal parasite of the fish. They can hardly be larvae, like, for instance, those of a *Trichina*, for in such a case some vestige of hooks, spines, or some other fairly durable organs of the larvae would have been visible. If they are eggs, the structure of the bodies is easily explained by supposing that the concentric shells which make them up are formed from the capsules of the egg. Certainly they are degenerated bodies, as is indicated by the presence of the highly refringent calcareous corpuscles, structures which seem almost invariably to be produced when the eggs or larvae of an entozoon die in the tissues of an animal incapable of acting as its host. How did they reach the muscle fibres of the fish? It is probable that, in some way or other, the eggs of a parasite inhabiting some organ of the hake had gained admission to the blood stream, and were carried along until they reached the capillaries. Being larger than some (or most) of the latter, they have become arrested there, and the life-history being now summarily interrupted, they have died. The outer fibrous investment is, then, the remains of the capillary wall, with, no doubt, some inflammatory tissue. The Fish Inspector, struck with the peculiar appearance of the flesh, promptly condemned the fish, and no doubt rightly, since it may be stated as a general precept that any very unusual structures indicate the undesirability of utilising the flesh of an animal in which they occur as human food. But in this case it is probable that the flesh of the hake was quite harmless.

Two Plaice with external tumours.

In October, 1908, two plaice were sent to the laboratory by the Board of Agriculture and Fisheries. There were large and prominent tumours on the skin of each. In view of the great interest that would attach to the discovery of cases of malignant tumours in fishes taken from the open sea, some considerable attention was paid to the nature of the structures in question. It proved, however, that the growths were not malignant; nevertheless, they may be worthy of detailed description.

Plaice A. Granulation Tissue Tumour.

The fish was a mature female 49 cm. in length. The stomach and intestine were empty. The viscera were, apparently, normal, and the fish was in good condition.

Fig. 2, Pl. IV, is a photograph, nearly natural size, of the tumour on the skin of this plaice. It was situated on the ocular side, about half-way between the anus and the root of the tail: about one-fourth of it was dorsal to the lateral line. The growth was roughly circular in shape, about 35 mm. in diameter, and raised up above the general level of the skin about 5 to 10 mm. The skin was broken all round the periphery of the growth, and raised to nearly the upper level of the latter. The substance composing the tumour was dead white in colour, and consisted of dense fibrous tissue. It was slightly excavated in the centre, as shown in the photograph. Perhaps part of it had been rubbed away in handling the fish. There was no pus tissue.

A large area of skin immediately round the tumour was abnormally pigmented, being dense black in colour. This is not very well shown in the photograph. This patch of skin stood out very distinctly from the rest, shading away quite sharply into the surrounding pigment.

When the fish was received the colouring of the ocelli on the rest of the skin was distinct and normal.

Directly underneath the growth thus described, and on the blind side of the fish, was a healed scar. This was indicated by an indistinct line, on either side of which was an area of skin devoid of scales.

The tissues of the fish, muscles, liver, kidney and blood were examined for the presence of parasites; but when I had first the opportunity of seeing them, these parts were in a very bad state of preservation. It is perhaps inevitable, but none the less unfortunate, that such interesting specimens as this are almost always in such a state, when received, that methods of exact histological investigation cannot be applied. There was, however, no indication of the invasion of the plaice by any obvious internal parasite capable of withstanding imperfect preservation.

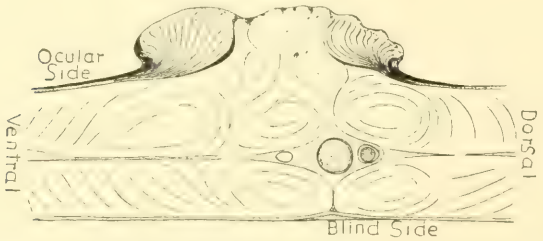

FIG. 17. Plaice with tumour. Transverse hand section of part of the fish through the tumour. Nearly natural size.

Fig. 17 represents the appearance of a hand section made through the middle of the tumour, and it will be seen that the greater part of the substance of this is composed of the greatly altered integument. All round the periphery of the growth, and extending towards the centre for about one-third of the diameter of the tumour, the skin is thickened and frayed out. By far the greater part of this thickened part of the integument is formed by the connective tissue bundles of the dermis, which spread out (in section) in a fan-like manner. Between these cuticular connective tissue bundles is a quantity of dense, wavy, fine, fibrous tissue; and towards the surface of the growth this intercalated tissue becomes predominant and is exposed. The core of the growth is formed by a mass of the same kind of dense fibrous tissue, and, as shown in the figure, this extends downwards to near the vertebral column. The arrangement of the muscle bundles of the trunk is roughly indicated in the figure, and it will be seen that hardly any of the substance of the tumour is made up of muscular tissue. Here and there indeed, scattered muscle bundles, or even isolated fibres, can be seen in stained sections, but these are not at all prominent, and they are present there because the foreign fibrous tissue has grown out from between the muscle bundles, and forced the latter apart.

The whole is probably a healing tissue—a conclusion made by Prof. Annett, of the Department of Comparative Pathology at Liverpool University. Probably the fish had received some injury: if so it must have been considerable, and a comparatively large amount of tissue must have been actually removed. In a fish like the plaice, comparatively small wounds heal quickly, and leave but little trace. Even the wound made by passing the silver wire, used in "marking" those fishes, through the body near the dorsal fin, hardly ever becomes greater, never suppurates, and even after two years during which period the wire, bone button, and brass label have been attached to the fish, there is hardly any enlargement of the hole through which the wire passes. Fishes like plaice, flounders, halibut, turbot and brill are occasionally found with the initials of some fisher-lad, or sporting yachtsman, scored with a knife on the side. Such wounds form clean, not very conspicuous, scars, healing perfectly. Sometimes a fairly large piece of the body of the fish, along the back, or along the ventral side, behind the anus, may be bitten out cleanly by some other fish. In such a case a clean healed surface is formed. Even such comparatively delicate fish as the whiting, haddock, or mackerel, are occasionally found with a rubber band, or ring, sprung on to the body behind the gills. This causes a constriction from the continual pressure of the rubber band, but the skin is seldom damaged. Plaice and flounders are often caught with split tails and fins, sometimes perfectly healed. Even when these injuries result from the handling of plaice or flounders in the trawl net, and when the fishes are kept in aquaria, the injuries heal. It is usually in the cases of fishes like the sole and dab, which possess strongly ctenoid scales, that injuries to the skin are likely to prove of a serious or fatal nature. Probably a sole cannot afford to have even a comparatively small area of skin rubbed bare of scales: in such a case the fish usually dies.

The adventitious tissue present in the skin and core of the growth described above, consists, then, of granulation tissue produced to fill up and heal a fairly considerable cavity resulting from some mechanically caused injury. The very striking annular area of pigment round the growth is the result of an inflammatory process. There is always black (and red) pigment in the skin of the plaice, and the former has been produced in abnormally great quantity as the result of the increased blood supply in the region of the healing wound. The conclusion follows, of course, that we have not to deal here with a tumour properly so-called, either benign or malignant.

Plaice B. Fibroma.

This was a mature female 40 cm. in total length. It was apparently in good condition and well nourished The stomach and intestine were empty.

There was a very conspicuous tumour, or growth, on the head of the fish, on the blind side. The general appearance of the fish is shown in fig. 1, Pl. IV, and it will be seen that the growth lies behind the angle of the mouth, and over the inter- and pre-opercular bones. The tumour is roughly elliptical in section (section made in the true horizontal plane of the fish), and the diameter of the major axis is about 23 mm. The tumour is about 25 mm. high (in the dorso-ventral plane of the fish. It is rather rough at its distal surface, as if part had been removed mechanically in handling the fish. It is firm and hard, the integument being continued over most of its surface. The distal extremity is ragged, apparently necrosed, but this, I think, is due simply to mechanical injury. The tumour being on its blind side, it would obviously become rubbed while the fish was feeding, or grubbing about in the sand. The growth is smooth, cheesy-looking, not very vascular, except at its proximal extremity.

As before, a rather prolonged search was made in the intestine, in the tissues of the liver, kidneys, spleen, and in the blood, for parasites, protozoan or entozoan. Nothing of the kind was found, but, as in the case of the other fish, the preservation was very imperfect. It always is so in these interesting specimens! Blood parasites, for instance, could not possibly have been detected, even if they had been originally present. Entozoan parasites, or larvae, or other stages included, or encysted in the muscles, gills or skin, might have been preserved, but I could find no such bodies. We may conclude that the growth is not the result of a parasitic invasion. Neither is it a healing tissue, as in the case of Plaice A. There are no indications of a wound. The tumour is attached to the integument by a comparatively narrow base, and it is even slightly constricted at its insertion. We cannot conceive of a healing tissue growing out in the manner of the growth in question. I conclude, then, that it is a true tumour—a *fibroma*. Histologically it consists of dense fibrous tissue, hard and compact as a rule, but here and there with slight spaces. There are also aggregations of connective tissue cells, but the wavy fibrous bundles are the predominant tissue. It does not appear to have any of the characters of a malignant growth, being apparently well bounded, though not encapsulated at its periphery. There may, indeed, be a permeation of the surrounding tissues, but from the nature of the growth it is difficult to be sure of this.

An abnormal specimen of the Brill.

In May, 1908, Dr. Jenkins sent me an abnormal specimen of the brill (*Rhombus laevis*), which had been forwarded to him by a fisherman. The head of this specimen is represented in fig. 18, and it will be seen that a condition frequently seen in various flat fish is present, viz., a partially arrested metamorphosis, the effect of which is manifested in the incomplete translation of the right eye. In a pleuronectid fish the shifting of one eye from its morphological proper side precedes the growth forward of the dorsal fin in the pseudo-mesial line. It sometimes happens, however, that this shifting of one of the eyes to its definitive side is delayed, or does not completely occur. Then the anterior growing extremity of the dorsal fin arches over this eye; perhaps it may later on fuse with the preocular part of the head, but as a rule a little hook is formed, a prolongation of the skeletal parts of the fin, and on this the rays are attached. This is the case with the specimen figured. There is a prominent hook-like process carrying the first six or eight

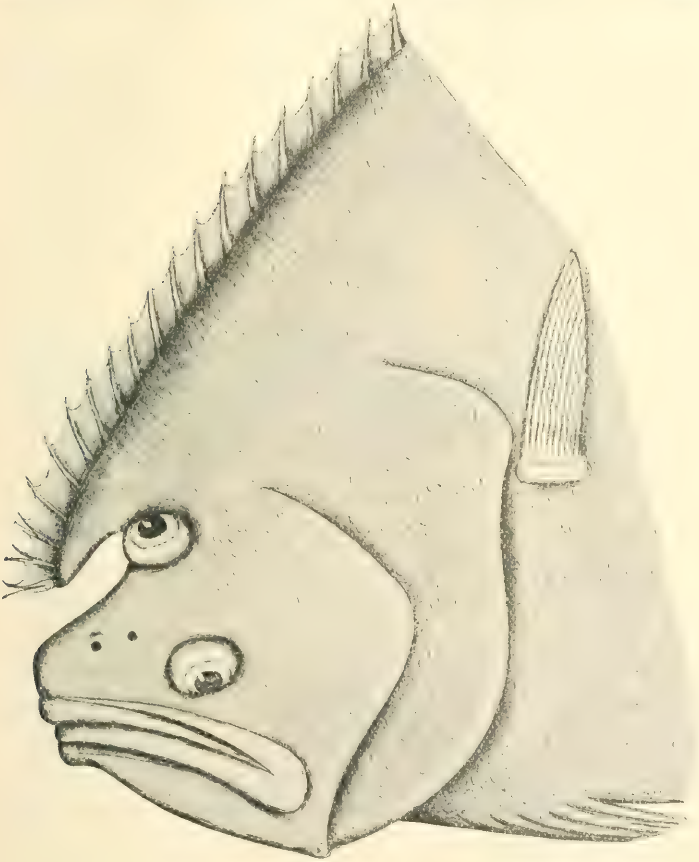

FIG. 18. Abnormal Brill. Nearly natural size.

dorsal fin-rays, and extending forward towards the snout, over the right eye. This eye is further apart from the other than is normally the case. It is not far from the dorsal line of the head.

The fish is ambicolorate, but its appearance when seen from the blind side is rather bizarre (fig. 1, Pl. III). The greater part of this side is as perfectly pigmented as is the left, ocular side. But part of the head is perfectly white. The skin covering the cheeks, the anterior and dorsal part of the head, the pre-operculum and inter-operculum, is colourless, but that covering the operculum and sub-operculum is perfectly pigmented. The coloration stops very exactly at the suture between operculum, sub-operculum, and inter-operculum. So much of the hook-like process as can be seen from the blind side is pigmented; so is the dorsal fin to its tip; and so is part of the skin covering the maxilla. The pre-maxilla and lower jaw are pigmented.

The specimen rather resembles that described by J. T. Cunningham,* but the unique conditions of reversal in the latter specimen are absent. The fish I describe is normal so far as its symmetry is concerned. It is an immature female, normal in every respect except for the features noted above. Cunningham points out that the arrested migration of the eye, and the consequent abnormality of the dorsal fin, occurs frequently in ambicolorate specimens of the turbot and, less frequently, in ambicolorate specimens of other Pleuronectidae. The ambicoloration in the brill described certainly corresponds with the abnormality in question. But I have seen more specimens showing these characters—ambicoloration and arrested metamorphosis among flounders than among any other Irish Sea flat fishes.

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* "A peculiarly abnormal specimen of the turbot." *Journ. Mar. Biol. Assn.*, Vol. VIII, No. 1, p. 44, Pl. 3, 1907.

PLATE III.

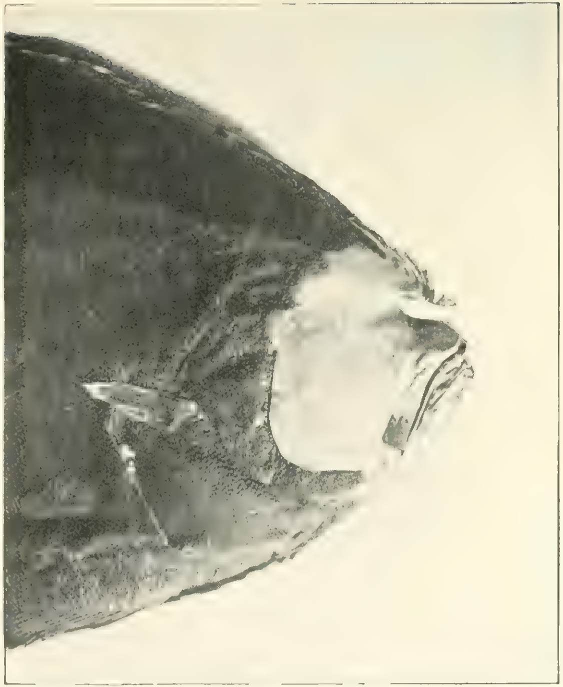

FIG. 1. Abnormal Brill: blind side.

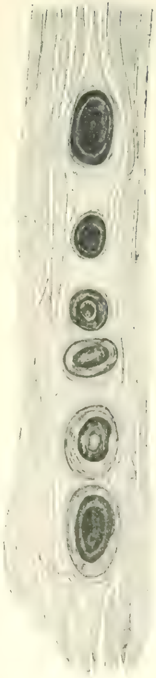

FIG. 2. Hake with parasites.

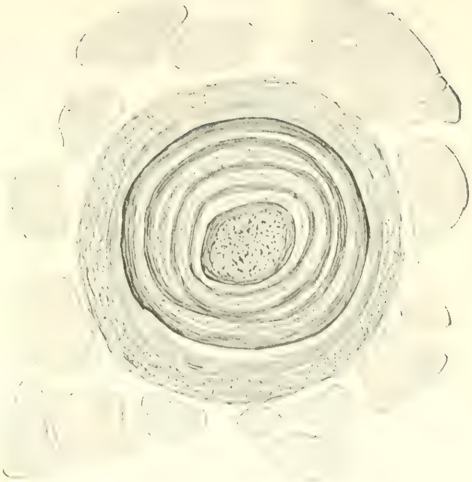

FIG. 3. Hake with parasites.

PLATE IV.

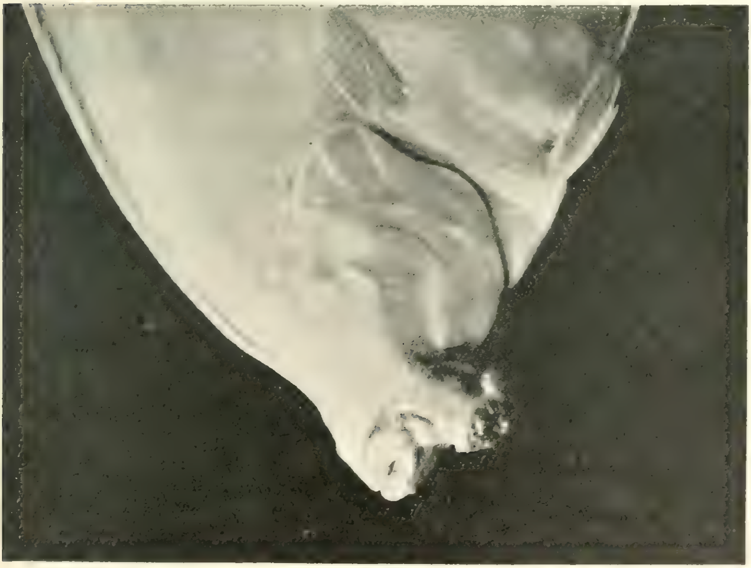

FIG. 1. Tumour on Plaice (B).

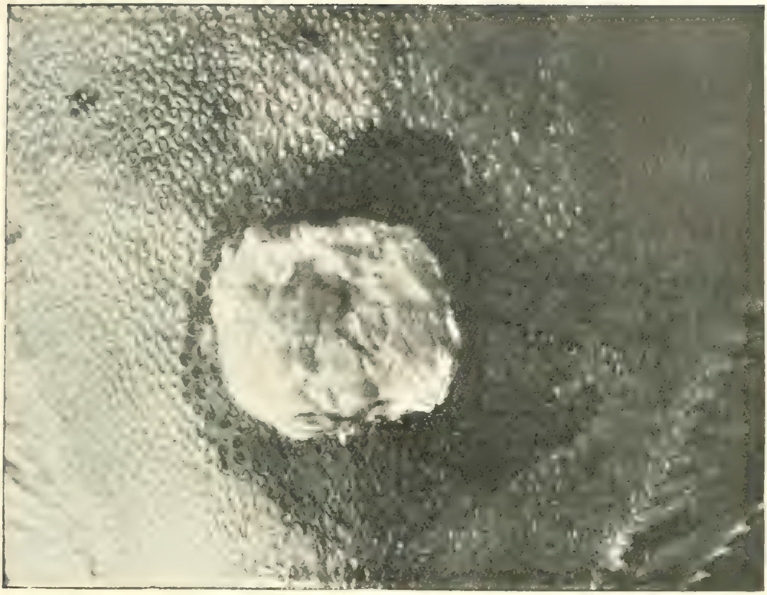

FIG. 2. Tumour on Plaice (A).

BACTERIOLOGICAL INVESTIGATIONS IN RELATION TO SHELL-FISH POLLUTION.

By Jas. Johnstone.

I.—THE LANCASHIRE AND CHESHIRE COCKLE GROUNDS.
II.—THE MUSSEL BEDS ON PIEL SHORE.
III.—EXPERIMENTS ON THE PURIFICATION OF POLLUTED MUSSELS.

I. Late in 1907 Dr. Jenkins suggested to me the advisability of examining the condition of the cockle beds on the Lancashire littoral; and during the last three months of that year, and the first three of 1908, various inspections and analyses were made. Dr. Jenkins and I visited Formby on 18th October, Flookburgh on 18th November, Ansdell on 25th November, Leasowe on 2nd December, and Silverdale on 11th December, 1907. On each occasion we examined the cockle-bearing sands for evidences of sewage pollution, and I collected samples of the shell-fish, and, in some cases, of the water on the sands, for bacteriological analysis.

Methods of analysis in the case of a cockle differ in detail from those employed for mussels and oysters. In the latter case it is generally useful to examine each mollusc individually, by taking a sample quantity of the contents of the stomach and intestine; and in this way one can ascertain the variations in liability to pollution of the shell-fish on different spots of the scar examined. This is, however, difficult in the case of the cockle, and the method employed was essentially that recommended by Dr. A. C. Houston.

About 50 cockles, collected from different parts of the bed in question, formed a sample. The shell-fish were transported in air-tight sterilised paint tins, and on arrival at the laboratory the tins were packed round with ice. In no case was an interval of more than 20 hours allowed to elapse between the times of collection and incubation.

Ten cockles were selected at random from the sample and washed under the tap. They were opened by sterilised knives so that the " fish " remained in one valve. Then, by means of sterile scissors, the soft parts of the mollusc were cut into as small pieces as possible, while still lying in the shell, the latter being held over a small sterile glass mortar. In this way all the bodies of ten cockles were cut up and put into the mortar. It is necessary to take some pains thoroughly to clean and sterilise the fingers, since the latter are almost sure to receive some of the liquid dripping from the shell into the mortar. The soft pulp in the latter is then thoroughly beaten up with the pestle until an emulsion of the soft bodies, with the liquor in the shells, is formed. Unless a homogeneous emulsion is prepared irregular results are obtained.

This emulsion is then poured into a flask and diluted to 100 c.c. with sterile water, and the whole is very thoroughly mixed. But it is impossible to obtain a uniform suspension in water of the soft parts of the molluscs. Therefore the flask is allowed to stand for a few minutes until the heavier parts of the solid matter have settled to the bottom. Probably the bacteria inhabiting the cockle are pretty evenly distributed through the liquid; but, at any rate, this must be assumed, for it is only the liquid, containing the finer particles in suspension, that can be examined. Ten c.c. of the liquid are then taken and added to 90 c.c. of sterile water in a second flask, and again 10 c.c. of the thoroughly mixed liquid in this second flask are added to 90 c.c of sterile water in a third flask. In this way four dilutions are made.

In Flask	I—1 c.c.	contains	0·1	part of a cockle.
,,	II— ,,	,,	0·01	,, ,,
,,	III— ,,	,,	0·001	,, ,,
,,	IV — ,,	,,	0·0001	,, ,,

In actual practice it was found that two dilutions were sufficient, but when examining a sample of cockles for the first time four should be made.

One c.c. of liquid from each flask was then taken and put into a Petri capsule. Neutral-red, bile-salt, lactose agar* had been previously melted, partially cooled, and then put into the incubator at a temperature of 42° C., the tubes standing in a large dish of water. One tubeful of the medium was then poured into each of the Petri capsules containing the cockle liquid, and the contents were rapidly mixed by slightly shaking and rotating the capsule. The latter were then allowed to cool, were inverted and incubated at 42° C. for 20 to 24 hours, at the most. After this period the plates were read and the crimson colonies were counted. Most of the latter grow in the deep and appear, from surface view, as little elliptically-shaped bodies. They are really lenticular in shape, for the colony grows in a direction perpendicular to the surface of the medium (in the direction of least resistance). Generally they are surrounded by a haze, which is fairly evident. All crimson colonies growing in the deep were counted.

Two plates were always made from each dilution.

Representative colonies from all the plates examined were then selected and sub-cultured on the surface of sloped nutrient agar in tubes. After 24 hours at 42° C. these secondary sub-cultures were again sub-cultured in the following sugar media:—Glucose, lactose, mannose, sucrose, dulcite, inulin, and adonite, all containing litmus. Litmus milk cultures were also made, and Voges' and Proskauer's reaction was tested for in the glucose cultures. All were incubated for 48 hours at 42° C. At first I examined the sugar cultures for motility of the bacilli, but later on abandoned this character as useless.

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* Grünbaum and Hume, *British Medical Journal*, June 14, 1902. The medium employed was prepared in the Pathological Department, Liverpool University.

In each case 1 c.c. of the cockle liquid in each flask was incubated anaerobically in litmus milk previously heated to nearly 100 c.c. and then cooled rapidly. By the "Enteritidis reaction" is meant the clotting of the milk after 24 hours' strictly anaerobic incubation; the appearance of acid, and extensive disruption of the clot by gas formation. No further cultures and no inoculations were made.

I think it essential to give the details of the analyses, since future examination of some of the cockle beds may prove to be of great importance, and if such analyses are made and their results compared with those recorded here the comparison will hold good only if the methods employed are identical. There is, unhappily, no doubt that different bacteriological methods of enumeration of *Bacillus coli* in shell-fish may give strikingly discrepant results, and whether or not the method adopted above is the best, comparison analyses should be made by means of it.

I give now the details of the analyses, stating in each case the results of the primary cultures, as well as those of the tertiary sub-cultures.

1. The Formby cockle bed.

The samples were collected one hour before low water: (*a*) from Formby shore near a gutter on the sands and W.S.W. from the old Victoria Beach mark; and (*b*) from the seaward side of the same gutter, and as near as possible to No. 2 Black Buoy in Formby Deep. The sand was very clean and covered here and there with a scum of diatoms. There is no source of pollution nearer than the mouths of the River Alt. The projected Crosby sewer outfall was not at the time discharging, and had not, in fact, been completed.

FORMBY: RESULTS OF PRIMARY CULTURES.

Dilution.		No. of Red Colonies.	Enteritidis Reaction.
a	1	12 (50)	Typical
	2	2 (sterile)	Discolouration and clot
	3	Sterile (sterile)	No change [only
b	1	45 (45)	Typical
	2	2 (3)	Not typical
	3	Sterile (sterile)	Not typical

The figures in brackets give the results of the duplicate analyses. Duplicate enteritidis cultures were not made.

FORMBY: RESULTS OF TERTIARY SUB-CULTURES.

Sub-culture.	Glucose.	Lactose.	Mannose.	Sucrose.	Dulcite.	Adonite.	Inulin.	Milk.	V. and P.
1	a g	a g	a g	o	o	o	o	a c	o
2	a g	a g	a g	a g	o	o	o	a c	o
3	a g	a g	a g	o	o	o	o	a c	o
4	a g	a g	a g	o	o	o	o	a c	o
5	a g	a g	a g	o	o	o	o	a c	o
6	a g	a g	a g	o	o	o	o	a c	o
7	a g	a g	a g	o	o	a	o	a	o
8	a	a g	a g	a g	o	a	a	a c	o
9	a	a	a	a	o	a	a	o	o
10	a g	a g	a g	o	a g	o	o	a c	o

In this and other tables a = acid formation; g = gas formation; d = discolouration; c = clot; o = no reaction. V. & P. = Voges' and Proskauer's reaction.

Formby: Results of Primary Cultures—Further Analyses.

Two samples were collected again on February 11th, 1908. They were taken from the sands about 100 yards S.W. from Crosby Beach Mark. The results are as follows:—

	Dilution.	No. of Red Colonies.	Enteritidis Reaction.
a	1	5	Typical
	2	1	Atypical
b	1	6	Typical
	2	1	Atypical

2. The Flookburgh cockle beds.

The samples were taken from a place on the sands approximately S.W. by S., and two miles distant from Humphrey Head. The fishermen were working all round. One sample (*a*) was taken from a fisherman's bag, and the other (*b*) directly from the sands, in the track of a "Jumbo." About 200 yards from this place was a shallow sand-pool, and a sample of water was taken from this. This water was slightly turbid, doubtless because the men washed the cockles in it.

The Flookburgh cockle sands appear to me to be as free from pollution by sewage as any place round the British Isles can well be. There are no great towns near them, and the rivers flowing into the Bay are very clean. It is such a place as one might expect to be above suspicion, and this is indeed what the bacteriological analyses indicate.

One c.c. of the water collected was inoculated, in duplicate, in neutral red agar, as above. Both plates were sterile. One c.c was tested for the Enteritidis reaction and also proved sterile.

FLOOKBURGH: RESULTS OF PRIMARY CULTURES.

	Dilution.	No. of Red Colonies.		Enteritidis Reaction.
a	1	1	(5)	Atypical
	2	Sterile	(sterile)	No change
	3	Sterile	(sterile)	No change
b	1	Sterile	(1)	Typical
	2	Sterile	(sterile)	Typical
	3	Sterile	(sterile)	No change

The seven colonies obtained were sub-cultured.

FLOOKBURGH: RESULTS OF TERTIARY SUB-CULTURES.

Sub-culture.	Glucose.	Lactose.	Mannose.	Sucrose.	Dulcite.	Adonite.	Inulin.	Milk.	V. and P.
1	a g	a g	a g	o	a g	o	o	a c	o
2	a g	a g	a g	o	o	o	o	a c	o
3	a g	a g	a g	o	o	d	o	a c	o
4	a g	a g	a g	d	o	o	a	a c	o
5	a g	a g	a g	a g	a g	o	a	a c	—
6	a g	a g	a g	o	o	o	o	a c	o
7	a	a g	a g	o	o	o	o	a c	o

3. The Ansdell cockle beds.

Two samples were collected on the sands near Fairhaven Lake: (*a*) near the Lake itself, and (*b*) further away and on the seaward side of a gutter, on to the shore side of which emptied a sewer. A water sample was taken from the gutter, over against the sewer outfall; but on the opposite side, and to windward. There was a strong S.E. breeze, and there had been much snow and rain, so that the water in this gutter was probably less polluted than it would have been in fine weather.

The cockle beds at Ansdell and all along this shore are probably highly polluted. In addition to the discharge from a number of local outfalls the sea must be polluted from the water flowing out of the Ribble.

ANSDELL : RESULTS OF PRIMARY CULTURES.

	Dilution.	No. of Red Colonies.	Enteritidis Reaction.
a	1	200 (216)	Typical
	2	6	Typical
	3	1	No change
	4	1	No change
b	1	200 (150)	Typical
	2	13	Typical
	3	2	No change
	4	Sterile	No change

Water Samples :—

1 c.c. contained 15 red colonies ; enteritidis reaction absent.
1 c.c. .. 47 .. ..

ANSDELL : RESULT OF TERTIARY SUB-CULTURES.

Sub-culture.	Glucose.	Lactose.	Mannose.	Saccrose.	Dulcite.	Adonite.	Inulin.	Milk.	V. and P.
1	a g	a g	a g	o	a g	o	a	a c	o
2	a g	a g	a g	o	o	a	a	a c	o
3	a g	a g	a g	o	o	a g	o	a c	o
4	a g	a g	a g	o	o	o	a	a c	o
5	a g	a g	a g	o	o	o	o	a c	o
6	a g	a g	a g	o	o	o	o	a c	o
7	a g	a g	a g	o	o	o	o	a c	o
8	a g	a g	a g	o	o	a	o	a c	o
9	a g	a g	a g	a g	a g	o	o	a c	o
10	a g	a g	a g	o	o	a	a	a c	o

4. Leasowe cockle bed.

Two samples were collected from about the same place that is, near the Wallasey end of the Leasowe embankment. There was a little gutter running seaward just about the part of the sands where the samples were collected. Only one man was cockling, and he was washing the shell-fish in the water of this gutter. A sample was therefore taken. It was very fresh. The sands at Leasowe are very clean, and there was no evidence of pollution.

LEASOWE: RESULTS OF PRIMARY CULTURES.

Dilution.		No. of Red Colonies.	Enteritidis Reaction.
a	1	10 (3)	Typical
	2	Sterile	Atypical
	3	Sterile	Atypical
b	1	5 (6)	Typical
	2	Sterile	Typical
	3	Sterile	Typical

Water Sample :—

1 c.c. contained one red colony.
1 c.c. was sterile.

LEASOWE: RESULTS OF TERTIARY SUB-CULTURES.

Sub-culture.	Glucose.	Lactose.	Mannose.	Sucrose.	Dulcite.	Adonite.	Inulin.	Milk.	V. and P.
1	a g	a g	a g	o	o	a g	o	a c	o
2	a g	a g	a g	o	o	o	o	a c	o
3	a g	a g	a g	a	a g	o	o	a c	o
4	a g	a g	a g	o	o	o	o	a c	o
5	a	a	a	a	o	a g	o	a c	o

5. The Silverdale cockle beds.

Two samples (*a* and *b*) were taken from the sands near a perch situated on some scar ground. Humphrey Head was bearing about N.W. No cocklers were working on the sands at the time when the shell-fish were sampled. A hole was made in the sand and a sample of water was collected. This was very fresh. Some distance landward from the place where the cockles were taken was an extraordinary growth of a species of *Enteromorpha*. The alga was growing in large tufts on the sands and caused the latter to aggregate and harden so as to form little hillocks, which made walking quite laborious. The sands were very clean

SILVERDALE: RESULTS OF PRIMARY CULTURES.

	Dilution.	No. of Red Colonies.	Enteritidis Reaction.
a	1	3, (6), (2)	Typical
	2	Sterile	Typical
	3	Sterile	Atypical
b	1	2, (4), (sterile)	Typical
	2	Sterile	Atypical
	3	Sterile	Atypical

Water Sample:—

1 c.c. was sterile: enteritidis reaction atypical.
1 c.c. ,, ,, ,, ,, absent.

SILVERDALE: RESULTS OF TERTIARY SUB-CULTURES.

Sub-culture.	Glucose.	Lactose.	Mannose.	Sucrose.	Dulcite.	Adonite.	Inulin.	Milk.	V. and P.
1	a g	a	a g	a	o	a g	o	a	positive
2	a g	a g	a g	o	o	o	o	a c	o
3	a g	a g	a g	a	a	o	a	a c	o
4	a g	a g	a g	o	o	o	o	a c	o
5	a	a	a	a g	o	o	a	a c	o
6	a g	a g	a g	o	o	o	o	a c	o

6. Southport cockle beds.

Two samples (*a* and *b*) were collected: (*a*) from the sands just East from Southport Pier and (*b*) from near the same place, but close to a small pool on the sands. Several Banks fishermen were cockling at the place from which the latter samples were taken. The sands were very clean, and there were no indications of sewage pollution.

SOUTHPORT: RESULTS OF PRIMARY CULTURES.

Dilution.		No. of Red Colonies.	Enteritidis Reaction.
a	1	1 (sterile)	Typical
	2	Sterile	No change
b	1	2 (2)	Typical
	2	Sterile	No change

No tertiary sub-cultures were made.

Conclusions from the Results of Cockle Analyses.

The results of the above analyses may now be arranged so as to express the relative pollution in each locality. For this purpose the numbers of red colonies growing in neutral-red, bile-salt, lactose agar are taken as the indices of the amount of pollution. I have given test-reactions in the cases of all the analyses except the last one, but in the present state of our knowledge of the cultural reactions of the organisms closely allied to *Bacillus coli communis*, and pending some more critical examination of the value of the tests usually employed than has yet been attempted, it is as well to speak only of "colon-like organisms." Probably we may regard all those growing on the medium mentioned as belonging to this category, without, of course, committing ourselves to the view that they are necessarily of human intestinal origin. The following table gives the results of these counts. The numbers are "colon-like organisms" per cockle. In almost every case the numbers are averages deduced from the examination, in duplicate, of 20 shell-fish. The results of the enteritidis reactions may be neglected in the meantime. It would appear that there is no exact correspondence between the distribution of the organisms exhibiting this reaction and *B. coli*.

NUMBERS OF "COLON-LIKE" ORGANISMS CONTAINED IN ONE COCKLE FROM THE FOLLOWING LOCALITIES.

Ansdell	1915
Formby	272
Leasowe	60
Silverdale	28
Flookburgh	17
Southport	12

There can be little doubt, I think, that the cockles from Flookburgh and Silverdale are above reproach. Indeed, one would come to that conclusion apart altogether from bacteriological evidence. The Southport shell-fish would appear from the above results to be the purest in our district. But while this may be the case with the cockles taken near Southport itself, and relatively high up the foreshore, it may not be the case with shell-fish taken from nearer the middle of the Ribble Estuary. The cockles from Ansdell are undoubtedly polluted, and this may be the case with the shell-fish in various parts of the shore adjacent to Lytham, St. Annes, and Blackpool. Indeed, it is difficult to see how the beds there can escape contamination. Much more caution is necessary in expressing an opinion with regard to the cockles from Formby and Leasowe shores. There is no direct evidence of the transmission of disease by means of the shell-fish from these places—at least I know of none—and this goes far towards depriving the equivocal bacteriological results presented above of any significance. Probably the bacterial contents of the shell-fish may represent only that general pollution of the sea which is to be observed almost everywhere in the neighbourhood of great towns, and which may be regarded as possessing no harmful significance. It is, of course, obvious that the construction of new sewer outfalls at either of these places would materially affect the question of the contamination of the shell-fish there. At the present time there is no evidence of "first-class," and presumably dangerous pollution.

II.—Mussels from Piel Shore.

During March and April of 1908 I made three analyses of mussels taken from Piel shore between the Life-boat slip and the old Slagbank. The analyses were made for a particular purpose and would have no special significance if it were not for the fact that during October and November of the same year a certain amount of mussel-fishing was practised in this very locality. The fishing resulted from the prevalent distress in Barrow due to unemployment, and the mussels were sold in that district. The results of the analyses may be recorded here.

First sampling, 30th March, 1908. The shell-fish were collected from the scar ground well down the beach. The methods of analysis were similar to those to be described in the case of the Conway experiment.

PIEL SHORE, 30TH MARCH, 1908: RESULTS OF PRIMARY CULTURES.

Mussel.	No. of Red Colonies.	No. of White Colonies.
1	32	20
2	85 + numerous patches	About 60
3	Numerous and fused	Numerous and fused
4	63 + several patches	34 + several patches
5	88	Several streaks
6	50 + one large patch	43 + several patches
7	156	13
8	22	3
9	135 + several patches	6
10	Numerous and fused	Numerous and fused

A number of red colonies were examined in pure subculture, and comparative bacterial counts, using ordinary nutrient agar, were also made. These results need not, however, be quoted. But it should be remarked that the above analysis indicates a considerable degree of pollution. The relatively large numbers of white (or translucent) colonies should be noted, for it is probable that excess of these colonies, growing on Grünbaum's neutral-red agar medium, is indicative of recent, and presumably potentially dangerous pollution.

PIEL SHORE, 27TH APRIL, 1908: RESULTS OF PRIMARY CULTURES.

Mussel.	No. of Red Colonies.	No. of White Colonies.
1	1 patch	0
2	27 + patch	0
3	1 + patch	0
4	None	0
5	10	0

The remarkable difference between the results of this and the last analysis should be noted. The sample of the 27th April, 1908, was taken high up the beach, from the remains of the piles of the old pier.

PIEL SHORE, 4TH MAY, 1908: RESULTS OF PRIMARY CULTURES.

Mussel.	No. of Red Colonies.	No. of White Colonies.
1	21	0
2	14	0
3	7	0
4	2 very small patches	0
5	5	0

This sample was taken from the same spot as that of the 27th April, 1908. The bacteriological results resemble those of the latter. Considered together, they show how important it is that the exact situation from which a sample is taken should be noted.

III.—Experiments on the Purification of Polluted Mussels.

A series of experiments were made during 1908 with the object of ascertaining the conditions under which polluted mussels might be expected to cleanse themselves when placed in unpolluted water. On June 3rd I met Mr. Roberts, an Inspector of the Fishmongers' Company, and we visited the Estuary of the Conway River. The possibility of dealing with the polluted shell-fish of that area by re-laying them in the comparatively clean water at the mouth of the Estuary presented itself as the only way out of the apparent *impasse,* which has resulted from the complaints made as to the condition of the shell-fish taken from the river. The idea is, of course, no new one, and a long series of experiments made by Professor Klein, for the Fishmongers' Company, seem to make it certain that an oyster or mussel will evacuate the greater number of sewage organisms contained in it, if it be placed for several days in quite clean sea-water. Nevertheless, it appeared very desirable to make experiments in the locality itself. A place at the entrance to the Estuary, on the Morfa Beach, and about S.E. from the Perch, was selected by us, and I took samples of water from a pool on the foreshore about half-way up the beach, and also samples of water from the channel immediately adjacent. It seems probable that the water covering this part of the foreshore from about half-flood, or half-ebb, to high water would be unpolluted, or at least would be no more polluted than the sea generally along this coast—a degree of contamination which has, probably, no dangerous significance. On the other hand, the water in the Channel during the last of the ebb would be expected to be polluted to a much greater extent, for it would contain the drainage into the upper part of the Estuary. Three water samples were therefore taken :—

I. From a pool on the Morfa Beach, well up the foreshore, in line with No. 6 Red Buoy on Great Orme's Head.

II. From the Channel as near as possible to the place where sample No. 1 was taken.

III. From the Channel further up the Estuary and nearly opposite the Perch.

Nine plates were made, using 1 c.c. of water in each case, and the results are as follows:

CONWAY ESTUARY: NUMBERS OF "COLON-LIKE" BACTERIA PER C.C.

Sample	I—Sterile. (sterile). (sterile);	average	0
,,	II—8, (13), (6)	,,	9
,,	III—30, (15), (13)	,,	19

each sample being examined in triplicate.

There seemed no doubt then that the water of the foreshore, well above low water mark, was much more pure than that in the Estuary during the last of the ebb tide. A later series of analyses of the latter water (2nd December, 1908, neap tide, at about low water), based on duplicate determinations of the bacterial contents of six samples collected between the Perch and Benarth Point (above the Conway Bridges), gave 33 as the average numbers of "colon-like" organisms per c.c. At the same time that I examined the water from Morfa Beach, a similar analysis was made by Professor Klein, and Mr. J. Wrench Towse informs me that Professor Klein reported that the water was "quite passable."

It seems very likely, then, that the water covering this part of Morfa Beach is much more pure than the water covering the mussels in the Conway Channel; and it is probable that if decidedly polluted shell-fish were re-laid on the former locality they would be under conditions enabling them to cleanse themselves. An experiment was therefore arranged in November of 1908. A quantity of mussels were raked from the bottom of the river almost underneath the Bridges (Sample I): another lot were raked from the river quite close up to Deganwy Sewer outfall (Sample II); and a third quantity (Sample III) were taken from the bottom of mid-Channel between Deganwy and the Perch. These mussels were placed in fish boxes, each box being numbered, and the latter were then put down on the beach at Morfa. The boxes were surrounded by large stones to prevent them from being carried away by any unusual sea. It did blow hard during the progress of the experiment, but the boxes were not shifted. A man was engaged to "stand by" the mussels for a fortnight and prevent any interference with them.

Samples were taken from each box before re-laying, and 30 mussels in all were examined individually. About 0·1 c.c. of the stomach juices (this is often as much as can be obtained) was taken from each mussel and plated on Grünbaum's neutral-red agar medium. The number of red colonies was counted after 20 hours' incubation at 42° C. It was difficult, in some plates, to make a precise estimation of the numbers of colonies present, on account of their abundance, which led to fusion. It would have been better to adopt Houston's method, but it was desired to investigate the individual, rather than the average pollution. The rounded numbers are estimated.

CONWAY PURIFICATION EXPERIMENT: MUSSELS BEFORE RELAYING ON MORFA BEACH: NUMBERS OF "COLON-LIKE" BACTERIA PRESENT PER 0·1 C.C. OF STOMACH JUICES.

Mussel.		No. of Red Colonies.	No. of White Colonies.
SAMPLE I From near Conway Bridges	1	Numerous and fused	–
	2	About 300	–
	3	About 400	–
	4	About 200	–
	5	128	6
	6	Numerous and fused	–
	7	Numerous and fused	–
	8	35	–
	9	150	–
	10	About 300	2
SAMPLE II From near Deganwy Sewer Outfall	11	151	No white colonies on any plate
	12	300	
	13	About 400	
	14	200	
	15	108	
	16	Numerous and fused	
	17	250	
	18	240	
	19	+300	
	20	Numerous and fused	
SAMPLE III From between Deganwy and Perch	21	+250	No white colonies on any plate
	22	124	
	23	150	
	24	300	
	25	36	

Judging from my experience of previous analyses of mussels from the Conway Estuary, I should say these shell-fish were polluted to a remarkable degree.

The samples referred to above were relaid on Morfa

Beach at low water of a neap tide, about noon on 17th November, 1908. On 21st November, 1908, the first samples after relaying were collected. They were taken early in the morning (4 to 5 a.m.) and were delivered at the laboratory about 11 a.m., and were analysed at 12 noon. The results are shown in the following table:—

CONWAY PURIFICATION EXPERIMENT: MUSSELS RELAID FOR FOUR DAYS ON MORFA BEACH: NOS. OF "COLON-LIKE" ORGANISMS PER 0·1 C.C. OF STOMACH JUICES.

Mussel.		No. of Red Colonies.	No. of White Colonies.
SAMPLE I	1	53	No white colonies on any plate
	2	250	
	3	Sterile	
	4	36	
	5	About 200	
	6	9 (and not characteristic *B. coli* colonies)	
SAMPLE II	7	40 (and not characteristic *B. coli* colonies)	No white colonies on any plate
	8	9 (and not characteristic *B. coli* colonies)	
	9	16	
	10	Sterile	
	11	75	
	12	About 100	
SAMPLE III	13	Numerous and fused; no change	No white colonies on any plate
	14	17	
	15	150 (but many were not characteristic *B. coli* colonies)	
	16	1 (not characteristic)	
	17	100	
	18	Sterile	

On 25th November further samples were collected and brought to the laboratory. As before, they were analysed a few hours after collection. They had been relaid for eight days. The results of analysis are shown in the following table:—

CONWAY PURIFICATION EXPERIMENT: MUSSELS RELAID ON MORFA BEACH FOR EIGHT DAYS: NOS. OF "COLON-LIKE" BACTERIA PER 0·1 C.C. OF STOMACH JUICES.

Mussel.		No. of Red Colonies.	No. of White Colonies.
SAMPLE I	1	250	No white colonies on any plate
	2	40	
	3	50	
	4	1	
	5	10	
	6	Numerous and fused; no change	
SAMPLE II	7	50	No white colonies on any plate
	8	27	
	9	Numerous and fused; no change	
	10	4	
	11	20	
	12	250	
SAMPLE III	13	10	No white colonies on any plate
	14	200	
	15	50	
	16	50	
	17	30	
	18	Numerous and fused; no change	

On 3rd December, 1908, the experiment was brought to an end, when I collected a sample from each box myself. The shell-fish were taken at noon, 3rd December, 1908, were stored in sterile tins, packed round with ice, from 6 p.m. to 11 a.m. on the following morning, when they were analysed. The results are:—

CONWAY QUARANTINE EXPERIMENT: MUSSELS RELAID FOR SIXTEEN DAYS ON MORFA BEACH: NOS. OF "COLON-LIKE" BACTERIA PER 0·1 C.C. OF STOMACH JUICES.

Mussel.		No. of Red Colonies.	No. of White Colonies.
SAMPLE I	1	7	No white colonies on any plate
	2	10	
	3	9	
	4	120	
	5	250	
	6	7	
SAMPLE II	7	120	No white colonies on any plate
	8	120	
	9	40	
	10	100	
	11	Sterile	
	12	60	
SAMPLE III	13	Numerous and fused; no change	No white colonies on any plate
	14	Numerous and fused; no change	
	15	25	
	16	About 250	
	17	8	
	18	150	

Now, reviewing the results of these experiments we find that in the original sample (that is, in the mussels before relaying in relatively pure water) there were large numbers of colon-like bacteria—five of these mussels contained so many that counting was impossible, and the average (round) number of colonies on the rest of the plates was 200. In the first sample, taken after four days' quarantine, five mussels had undergone no cleansing, but three were sterile (to the medium employed), and, omitting the five that had undergone no change, we find that the average number of colon-like bacteria isolated from the mussels examined was about 40. The second sample, taken after eight days of quarantine, contained six mussels that had undergone no change, but the average numbers of colon-like bacteria isolated from the remainder was about 30. The third sample, taken after 16 days' quarantine contained four mussels which had not cleansed themselves, and the remainder gave an average test count of 55 colon-like bacteria.

We find, then, that a decided reduction in the numbers of bacteria, belonging to the *Bacillus coli* group, took place in these mussels after relaying in relatively unpolluted water. In some cases the reduction amounted to total disappearance; that is, some of the relaid mussels in each sample must be regarded as practically free from sewage bacteria. This is certainly the report which I would have made with regard to mussels 6, 8, 10, 16, and 18 in the sample taken after four days; in mussels 4, 5, 10, and 13 in the sample taken after eight days; and in mussels 1, 2, 3, 6, 11 and 17, in the sample taken after 16 days. The original sample, taken before the beginning of the quarantine period, contained *no* mussels that could be regarded as practically free from pollution. Mussels 8 and 25 were not very seriously polluted, but all the rest—23 out of 25—were polluted to a remarkable extent. It should be noted, also, that only in this original, untreated, sample did the significant white colonies occur.

The fact that a small proportion of the mussels dealt with did not cleanse themselves to an appreciable extent is to be attributed to the defects of the experiment. The latter was carried out rather roughly. If, instead of laying down the shell-fish on the beach, they had been placed in large tanks, so as to ensure an effective circulation of water, the results would have been better.

As already stated, all the conclusions stated here have already been made by Klein in his experiments made for the Fishmongers' Company, and we have only attempted to verify the results of those experiments (which were made under laboratory conditions) in the case of experiments conducted in the open. It is clear that a considerable degree of cleansing follows when badly polluted mussels are relaid in such a situation where they receive only the unpolluted water of the flood tide stream; and that a period of four days is a long enough quarantine period. After four days little or no further cleansing takes place. The recommendation is obvious: Mussels taken from such highly suspicious grounds as those in the Channel from the Conway Bridges down to below Deganwy Sewer outfall ought to be relaid high up on the Morfa Beach, where the only water that reaches them is that of the flood-tide or the first portion of the ebb-tide, and kept there for at least four days. The precise arrangement and construction of the receptacles—tanks, ponds, cages, &c.—for containing these mussels is a matter of some little experiment: no apparent difficulty suggests itself. The expenses might be relatively great, but compared with the capital value represented by the

Conway mussel ground, and with the increased sales which would certainly result from the confidence, on the part of the purchaser, that the mussels bought were free from danger, these expenses would be inconsiderable. That such a system of quarantining polluted mussels is at the present time apparently impossible is due solely to the restricted powers possessed by the authorities concerned; and it is surprising that some of the fishermen do not attempt to make their trade much more lucrative by putting it in force themselves.

THE FILTRATION COEFFICIENT OF PLANKTON NETS.

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Descriptions of the methods now used in the quantitative study of the plankton, and some of the results gained by the application of such methods both at Port Erin and abroad, have already appeared on several occasions in the Transactions of the Liverpool Biological Society and this series of Reports. So far, however, no account has been given of the methods adopted to determine from what actual volume of water the catch (fished by a plankton net) has been filtered.

This is naturally of fundamental importance, since with the various types and sizes of nets now employed the volume of water filtered varies considerably, even though they be pulled for the same length of time, or with the same speed. For this reason, it would be impossible to compare the abundance of any form or the amount of plankton present at two places if at one a catch was made with a Hensen net and at the other with a Nansen (taking these two examples), unless the volume or number of the specimens making up the catch was reduced in each case to a common measure, namely the volume or number in a unit quantity of water. In short, we must have for each net a coefficient by means of which the relation of the catch to the volume of water from which it was abstracted can be readily determined.

The calculation of this coefficient is a somewhat difficult task, and at best we can only hope for approximate results, but, on the other hand, we must have some means of comparing catches made at different places and with different size and shape of nets. As regards the actual determination of the number of any species in the sea, that, as a solitary fact, has little scientific importance, and must not be taken as the aim of quantitative work. It is the comparison of daily or weekly catches for a long period showing the seasonal fluctuations in production, and how this varies according as variations in the environment may take place (even the relative "cloudiness" of the atmosphere appearing to affect plankton production), that should provide a rich field for future research.[*] There is, further, to be noticed, the inter-relation between one form and another, the phyto-plankton and the zoo-plankton; and lastly the diurnal oscillation from surface to deep waters, and vice versa, must be determined, and taken out from the other factors. Owing to the approximate nature of the calculations, it appears to me that whenever possible, a standard net should be used. The Hensen and medium Apstein nets fulfil practically all conditions, and their coefficients have been carefully corrected, though it will be seen that this is not sufficient, and an improvement would be the calculation of several coefficients to be adopted according to the various types of plankton being fished. The dimensions of the Apstein net and the coefficients are given at the end of this paper.

The following is a summary of the theoretical method of determining the coefficient which was employed by Hensen.[†] The filtration experiments are too complicated to be of general use, but by means of the resulting tables and the formulae, the method could be applied to other nets, though to my mind the empirical methods to be discussed later are more satisfactory.

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[*] Kofoid. *Bull. Illinois State Laboratory*, Vol. VI, 1903, Art. II, p. 483.

[†] Hensen. *Methodik. Ergebnisse der Plankton Expedition der Humboldt-Stiftung*, Bd. I, B. 1895.

It is obvious that the quantity of water passing through a ring that is hauled from a given depth at a given speed, is greater than the volume that would pass through the same ring under similar conditions if a net were attached to it. Further, the volume will be dependent on the following factors: (1) Shape of net; (2) Area of filtering tissue; (3) Nature of filtering tissue; (4) Area of opening; (5) Speed of pull.

The first problem to be tackled is the determination of the quantity of water that would pass through a unit area of any given quality of silk (Müllergaze—the best net material) in unit time, under different pressures.

It must be observed that this determination of the filtration capacity of Müllergaze must be made *under water*; the filtration must not take place in air or otherwise the results cannot be applied to the nets which are, of course, submerged when in action.

In Hensen's experiments (see Taf. V, *loc. cit.*) fresh water was led from a reservoir to a cleaning apparatus, consisting of a filter box made up of two halves of brass separated by a piece of No. 20 Müllergaze. Small openings in each half rendered it possible to remove any air which collected at the surfaces of the silk. From this filter, a tube conducted the water to a strong glass spherical vessel, the opening of the tube into the vessel being guarded also by Müllergaze. This vessel held a certain amount of air in order to reduce jerks in the water pressure.

From it, another tube conducted the water through a regulating cock which allowed the experimenter to control and regulate the pressure. The water passed from the regulator to the actual filtration apparatus, a brass cylinder which is permanently closed at one end, and which has a circular opening at the other, so constructed that a piece of the silk to be tested can be fixed over it in such a way as to prevent any water leaving, except through this tissue.

The tube conducting the water to this cylinder opened into one side near the closed end. Another tube opening also into the side, but nearer the open end, placed it in communication with a mercury manometer, by means of which the pressure of water in the cylinder (representing the pressure under which filtration was taking place), could be recorded. The whole cylinder with its connections to water supply and manometer, was immersed completely in water in a rectangular reservoir, for reasons stated above. This reservoir was supported on a table, the top of which had the form of a trough, so that any water flowing over the edges of the reservoir was collected by it. A short tube allowed this water to run out of the table trough so that it could be collected at any time in a flask kept under the tube, but which had its mouth guarded by an inverted evaporating basin placed over it.

Precautions must be taken to allow of easy removal of any air which generally collects in various parts of the apparatus during the experiment, and disturbs the results, and the opening closed by the gauze to be tested should be so constructed that the end can be taken off and the gauze cleaned with a sponge after each trial.

The procedure is as follows. Everything being in place, the water is turned on, the reservoir being already filled with the same up to the edges. The water passes through the cleaning filter, the large flask and the regulating cock, to the brass cylinder which it leaves by way of the tissue to be tested, passing through this into the reservoir. Since this is already full, a certain quantity overflows equal to the volume entering. The pressure is read off from the manometer and controlled by the regulating cock until it remains steady at the desired point. When constant conditions are obtained, a steady stream of water will be filtering through the silk tissue into the reservoir and a steady overflow from the latter will be collected by the table trough and led off by the overflow tube. The water is, therefore, passing out of the latter at the same speed as it passes through the area of silk closing the cylinder. The cover of the collecting flask is now quickly removed at a signal, the water runs steadily into the flask, and after a certain number of seconds have elapsed the cover is quickly replaced. The volume of water in the flask will be equal to the amount which passed through the area of silk taken during the number of seconds the flask was uncovered, and at the pressure recorded.

Two tables giving the quantity of water filtering through 1 sq. centimetre of Müllergaze (various grades) in one second, at various pressures, were drawn up by Hensen, and appear in his Methodik on pages 86 and 94. They will be applied in the way to be subsequently shown.

If a ring with no net attached to it were pulled through the water, the quantity of water passing through the ring would be equal to Onv, where O = area of opening, n = number of seconds the pull lasts and v = speed in centimetres per second.

The speed of outflow of liquids through an opening can be calculated from the Torricellian theorem, and by the application of this Hensen concludes that—

$$s = \frac{v^2}{2g} \qquad [1]$$

where s = the pressure equivalent to the speed, v = speed of pull and g = acceleration of gravity = 980·9 centimetres.

As soon as a net is hung on to the ring, the simple conditions given above no longer prevail, for the net introduces a resistance, under the action of which part of the water before the opening is pushed away to one side. This pressure d, which resists the entrance of the water, has now to be found.

It is obvious that the same quantity of water passes through the entrance to the net, as filters out through the net walls, a constant speed of pull being assumed. It may be expressed shortly as—Inflow = Outflow.

Now, if a pressure d occurs in the net opening, the inflow per second will no longer be $Ov_{(s)}$ where v denotes speed of pull to which by equation [1] the pressure s belongs and O = area of mouth opening, but will now be

$$Ov_{(s-d)} \qquad [2].$$

It assumes, however, that one important condition has been fulfilled, namely, that the resistant pressure d is uniform all over the net as well as at the entrance, and this will be shown later to be incorrect. Taking the cylindrical net first as an example, the outflow must be $Nw_{(d)}$ where N = filtering area of net in sq. centimetres, and w = the quantity of filtrate per sq. centimetre at the pressure d.

The equation now for inflow and outflow is—

$$\underset{\text{Inflow.}}{Ov_{(s-d)}} = \underset{\text{Outflow.}}{Nw_{(d)}} \qquad [3]$$

In this equation O, N, s and v are known and d and w are dependent on one another, and have been calculated by the filtration experiments described above. The following example shows how these tables and the formulae are applied to calculate the coefficient for a cylindrical net. The opening has an area of 6·147 sq. centimetres, the area of filtering silk is in the same proportion to the opening area as 1 : 0·00124, the silk is No. 20 Müllergaze, and speed of pull = 53·5 cm. per second. N in equation [3] must be brought over to the other side so that it runs—

$$\frac{v_{(s-d)} \cdot O}{N} = w_{(d')} \qquad [4]$$

d, d', d'' . . . are trial values for d, which are substituted until the equation agrees.

By [1], $s = \frac{v^2}{2g}$. and v in this example $= 53\cdot5$

$$\text{hence } s = \frac{53\cdot5^2}{2g} - \log.\ 53\cdot5^2 - \log.\ 2g$$

$$\begin{array}{ll} = \log.\ 53\cdot5^2 & 3\cdot45671 \\ \log.\ 2g & 3\cdot29265 \\ \hline \log.\ s & 0\cdot16406 \end{array}$$

$$s = 1\cdot459$$

For the first trial value for d, take $0\cdot02$. Then

$$s - d = 1\cdot459 - 0\cdot020 = 1\cdot439.$$

It is now necessary to find v corresponding to this new pressure $s - d$.

Again from [1] $v^2_{(\text{at press. } s)} = s \times 2g$

$$\text{hence } v^2_{(\text{at } s-d)} = (s - d) \times 2g$$

$$\begin{array}{lr} s - d = 1\cdot439 \quad \log. & 0\cdot15806 \\ \log.\ 2g \quad = & 3\cdot29265 \\ \hline \therefore \log.\ v^2 = & 3\cdot45071 \\ \log.\ v = & 1\cdot72536 \end{array}$$

Apply this in equation [4]—

$$\begin{array}{lcl} \log.\ v_{(s-d)} & = & 1\cdot72536 \\ \log.\ O & = & 0\cdot78866 \\ \hline \therefore \log.\ v_{(s-d)} \cdot O & = & 2\cdot51402 \\ \log.\ N & = & 3\cdot69683 \\ \hline \text{Hence } \log.\ w_{(d')} & = & 0\cdot81719 - 2 \\ & & 0\cdot065644 \end{array}$$

Reference to the experimental tables shows that at a d of $0\cdot02$ the $w = 0\cdot064644$. By the above equation, however, it comes out to 0·065644, so that the d, taken as trial value (0·02), was evidently too small. The difference (0·001) between 0·064644 and 0·065644 corresponds to a d difference of 0·0003153. Hence the new trial value of d is:—

0·020000 (originally taken)
0·0003153

d = 0·0203153

This is applied exactly as d in the previous calculation and so the d is altered until both sides of the equation finally agree. When this is the case the $v_{(s-d_n)}$ is taken and applied in the following:—

$$\frac{\text{Volume that would pass through opening ring if } \textit{no} \text{ net attached}}{\text{Volume that would pass through opening ring when net attached}} = \phi = \frac{v_{(s)} \,.\, O}{v_{(s-d_n)} \,.\, O}$$

ϕ is the coefficient representing the fraction which the area of the cross section of column of water actually fished bears to the area of net mouth. For the example taken

$$\log.\ v_{(s)} \,.\, O = 2·51703$$
$$\text{and } \log.\ v_{(s-d_n)} \,.\, O = 2·51397$$

$$\text{Hence } \log.\ \phi = 0·00306 = 1·00707$$

The catch must be multiplied then by 1·00707 to give the volume in a column whose cross sectional area is that of the net mouth. This reckoning is, however under the assumption that the pressure is uniform all over the net.

This can be accepted for nets having a large filtering area in proportion to the opening, but it is evident from a series of catches made by Hensen with the same net and gradually increased area of mouth opening, that the larger the mouth, the more incorrect does the ϕ become.

For example—

Area of opening sq. centimetres.	Speed of pull cm. per second.	Volume under square metre of surface water calculated from the separate catches by the theoretically determined ϕ
6·1	53	284
12·6	47·9	262
24·4	55·2	234
45·7	54·3	190 (?)
90·2	52·7	189
367·7	53·6	184
1226·0	51·9	189

Thus the coefficient ϕ is not sufficiently great to cover the loss in catches made with wide mouthed nets. Since the pressure s used and determined in the reckoning is correct, something must be wrong with the pressure d, and that is the assumption, made at the beginning, that it was uniform all over the net. As a matter of fact in a plankton net the filtration pressure varies and just as at the proximal edge only a portion of the water is filtered, so at the following zones only a portion of the residue is filtered, until, finally, at the apex of a long net, only a minimal quantity of water passes through. This fact is of great importance in the practical employment of the net because too often the upper parts of the net (especially under the large ring of the conical head-piece in the Hensen nets) are insufficiently washed down and a large quantity of plankton caught here where filtration is greatest, is left adhering to the silk. Hensen attempted to calculate out theoretically, therefore, the correction necessary for this variation, but this is attended with many difficulties, and is best done empirically in the following way. This applies also for the conical net to be referred to shortly. Determine first the ϕ for the net, with, however, a narrow mouth instead of its normal wider one. Having found this, a series of catches are made under good weather conditions with the same net, first with the narrow mouth and then with the wider mouth. If now the average volume of catch with the narrow mouth is reduced to the volume under the square metre of surface, by application of the coefficient ϕ, it is easy to find what coefficient is necessary, to bring the actual observed volume caught by the wide mouthed net, up to the same volume under the sq. metre. The new coefficient corrected for the variation due to pressure d, is termed ψ.

This implies, of course, a uniform distribution in the water whilst the series of catches was made.

For conical nets the procedure is practically the same, though the formulae are somewhat different. If a firm plate is pulled through the water with the surface perpendicular to the direction of pull, there will be a pressure from before and a pull from behind which, *added together*, cause a tendency to bend. If the plate is funnel-shaped, the pulling force z is divided into two components (parallelogram of forces), one, $z \cos a$ is applied in the direction of the funnel wall and the other, $z \sin a$ is applied perpendicular to it. The apical angle in the funnel is $2a$.

The conical net exhibits such a funnel, except that its walls are permeable. The pressure d is assumed as before to be uniform all over the net, the correction for this to be made approximately or empirically as described above.

Now, if $v(s)$ is the speed at which the net is hauled, the pull component on the outer net wall is *not* $s . \sin a$ because under the influence of the pressure d the current $w(d)$ streams out of the net, and this is accelerated by this pull. Hensen takes this pull component accordingly as d sin a, and finds that the reckoning can then be satisfactorily carried out which is not possible with s. sin a.

The net consists of a conical part, whose filtering area is C, and a cylindrical bucket whose filtering area is E. The equation runs

$$v_{(s-d)} \,.\, O = E w_{(d)} + C w_{[(1+\sin a)d]}$$

If E is multiplied by cos a and the product added to C, one obtains $N = C + E \cos a$ with only a very unimportant error, as conical area for the whole of the filtering tissue and the final equation becomes—

$$v_{(s-d)} \,.\, O = N \,.\, w_{[(1+\sin a)d]}$$

This is applied in the same way as the equation for the cylindrical net, trial values of d being taken until both sides agree.

Such was the theoretical method employed by Hensen. It is certainly extremely ingenious, but at the same time very laborious, and finally, as Hensen himself shows, the coefficient ϕ is only approximately correct, and must be corrected empirically.

It is far better, therefore, that the whole calculation be made empirically, if possible, and this is both easy and reliable, that is, of course, in comparison with the theoretical method that has been described, which I feel to be unsatisfactory. Certain points, however, remain to be considered. It appears that the coefficient of filtration for a net can and does vary within rather too wide limits. This has been emphasised by Kofoid, who pointed out that the stoppage due to deposits of organisms clogging the meshes altered considerably the coefficient. This can take place very easily in the sea when using No. 20 silk, and the catches are made at times in spring or autumn when diatoms are very abundant. In tropical seas this may also occur, and Professor Kofoid has drawn my attention to the fact that even at the equator a heavy diatom plankton may sometimes be encountered. Thus, in the "Albatross" expedition reports* we find: "It is most interesting to note the number of diatoms found in this tropical region. They have usually been considered as characteristic of more temperate and colder regions. On several occasions the surface waters were greatly discoloured by their presence." A radiolarian plankton would also soon stop up the meshes, and this applies also to a plankton containing many gelatinous forms—ctenophores, etc. This factor has received far too little attention from the Kiel school. Added to this are two other features of some importance. The difference between a new silk net and an old one of the same grade silk is considerable, and from Kofoid's experiments† it appears that a new silk net, even after having been shrunk by washing and pressing several times, catches at least fifty per cent. more than an older one. Furthermore, Hensen's experiments for the filtration coefficients of different grades of silk were made with filtered water which left no chance of comparison with conditions in seas or lakes. These difficulties can, to a certain extent, be overcome by determining empirically the coefficient, and by determining separate coefficients for the same net, to be applied according to the class of plankton and the quantity present. The best method is that of parallel catches with the net and with pump and tube. A series of these should be carried out in the different classes of plankton likely to be met with, and the coefficients noted for future use. The pump tube must be carefully raised and lowered vertically at a uniform speed through a certain stratum of water. The net is to be hauled up vertically, allowing no chance of horizontal towage, through the same stratum of water, the speed of haul being noted. The exact volume of water pumped up is, of course, known; the catch can be abstracted from this in two ways. First, if the comparison of volume caught is to be the basis of the coefficient, the water from the pump is filtered through *a net* of the same material as the net which is being examined, so that it may abstract approximately the same kind of catch as it would when pulled through the water. The net which is being used as filter must be floated on the surface of the water so that the filtering area is submerged, and some arrangement should be used to spread the water pumped into it, so that it does not hit one part with too great a force. This filtered catch is then fixed and centrifuged, in order to determine the volume. The catch made with the net is also fixed, centrifuged and the volume taken. Knowing now the volume of water which the filtered pump catch represents, it is easy to find how much water must have been filtered by the net to have given the volume of plankton caught by the latter.

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* "Reports on Scient. Results of 'Albatross' Exped.," Vol. V, *Mem. Mus. Comp. Zoology*, Harvard, 1906, p. 14.

† Kofoid. *Loc. cit.*, p. 263.

Another way would be to filter the water from the pump through hardened paper so that nothing but the smallest organisms would be lost, then to count, by the usual methods, some organisms in the catch which occur uniformly distributed in the area where the experiments are carried out, and which are caught accurately by both net and pump methods. Small forms which are lost by the net are therefore cut out, and even copepoda or metazoa which swim actively and generally are very sensitive to currents against which they move, may not be caught accurately by the pump and tube. Lohmann[*] states that with the speed of current attained in the tube in his experiments, this could not occur, and certainly the pump catches of copepoda are greater, apparently, than net catches, yet at the same time there must be an area round the pump-tube opening where the current is very slow, and here, certainly, such animals could move away.

Probably the constant motion of the tube up or down, diminishes this factor, since the pump opening is continually being brought into new regions. Species of *Ceratium* or fish eggs are reliably caught by both methods. In any case, these organisms will be counted in the pump catch filtered by paper, and also in the net catch. Knowing as before the volume of water brought up by the pump, which the number counted in the pump catch represents, it is easy to calculate what volume of water was filtered by the net to give the number of the organisms chosen and counted in the catch of the latter. Before any new net is tested as above described, it should be thoroughly washed with soap and water and pressed. This causes a considerable shrinkage which would otherwise take place during the first catches made with the net. A net should, further, not be kept in use for too long a time unless the coefficient is again tested, and whilst in use should be well washed down after each catch. On some occasions a very heavy plankton may be present so that the walls of the net are soon covered with a layer. When this is the case most coefficients will be disturbed, unless a net is used which has a very large filtering area and a narrow mouth, and very short hauls are made. Finally, when making volumetric estimations of the catch in the course of work. I believe it will be better to centrifuge the fixed catch for two minutes or so and then measure the volume, as carried out by Kofoid,* instead of taking the volume after settling for twenty-four hours.

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[*] Lohmann. *Wissen. Meeresuntersuch. Kiel Komm.*, N.F., Bd. X, Abt., Kiel, 1908.

Dimensions of Apstein Medium Plankton Net.

Diameter of opening, 14 cm.
Area of opening, 155·3 cm.
Diameter of net { at lower ring of conical head piece, 40 cm.
Diameter of net { at bottom where attached to filtering bucket, 6 cm.
Length of side of conical head piece, 20 cm.
Length of side of net, 100 cm.

The corrected coefficients, ψ, for the large Hensen net and the Apstein net are given by Lohmann† as 1·34 and 1·39 respectively for a speed of pull one metre in two seconds.

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* Kofoid. *Loc. cit.*, p. 254.

† Lohmann. *Wissenschaft. Meeresuntersuch.*, N.F., Band VII, p. 17, Kiel, 1903.

AN INTENSIVE STUDY OF THE MARINE PLANKTON AROUND THE SOUTH END OF THE ISLE OF MAN. PART II.

By W. A. Herdman, F.R.S., and Andrew Scott, A.L.S.

[Introductory Note.—During the past year (1908) the plankton work described in the last report has been carried out on very much the same lines as in 1907, with the double object (1) of studying the distribution of the plankton as a whole and of its various constituents, and (2) of attempting to arrive at some estimate of the representative value of samples. During the year as a whole ordinary tow-net gatherings have been taken at approximately weekly intervals from a small boat in Port Erin Bay, the practice being to make a traverse of the bay, across its middle, from the lifeboat slip on the south side to the rocks of the opposite shore. The nets used were ordinary open tow-nets of 14½-inch diameter at the mouth, and made of Dufour's No. 20 silk bolting cloth. These gatherings were fixed and bottled by Mr. Chadwick at the Biological Station and were sent periodically to Mr. Andrew Scott for examination. For about a month at Easter (practically the month of April) and for two months in summer (practically August and September) Professor Herdman made more frequent and more extensive collections from the yacht "Ladybird," both in the bay and also at sea. In this work he was assisted at Easter by Mr. W. Riddell, M.A., of Queen's College, Belfast, and in summer by Mr. Harold Drew, B.A., of Christ's College, Cambridge, and now Lecturer in Biology at the Plymouth Technical School. Both Mr. Riddell and Mr. Drew took part in the preservation and the first general examination of the samples, which were all sent eventually, like the rest, to Mr. Scott. The larger organisms, such as Medusae, *Sagitta* and Decapod larvae, were picked out and counted at Port Erin before measuring the sample. From Mr. Scott's numerical estimates of the species, and his own notes of the material, and the physical conditions when gathered, Professor Herdman has drawn up the present account of the collections and the discussion of results. These results are in some respects so different in detail from those of the previous year (1907) that it has been decided to continue the work on the same lines during at least another year. Several improvements in method have been introduced and others are contemplated, but these are additions rather than substitutions, in order that the results may be, as far as possible, comparable year by year. It is not necessary to describe again the methods of collection and of estimation of the samples; for these and other details, such as the positions of the observing stations (shown in fig. 10), reference should be made to last year's report.]

PLANKTON OF PORT ERIN BAY IN 1908.

We shall first of all separate the gatherings taken across the bay throughout the year from those taken out at sea, by means of the yacht. These bay gatherings were all single traverses, taken in a similar manner with similar nets (No. 20 silk), and are all 15 minutes hauls.

We have 155 surface hauls taken across Port Erin Bay throughout the year, from January 4th to December 30th. All months are represented, and nearly all weeks. January and March are the only months in which less than five hauls were taken, and in all the remaining months except February, May and July the numbers range from 8 in June and December to 42 in October. During some parts of the year the bay observations were almost daily. In the open sea, however, surface hauls were only taken when the yacht was at work, during April, August and September.

In April, a few additional hauls were taken with a coarser-meshed net (No. 6 "Double-extra heavy" silk) immediately after the ordinary gatherings, for comparison. In August and September this experiment was repeated, and a "weight" net (No. 20) was also occasionally towed near the bottom. From September 14th onwards to the end of the year, both fine (No. 20) and coarse (No. 6) nets are used on each occasion, the former in the traverse from south to north, and the latter on the return journey. In the following list the coarse net gatherings are marked "c" after the date, and the weight ones "w."

In this first list only the more important groups of organisms are given, the Diatoms, the Dinoflagellates and the Copepoda. Other less dominant groups and separate genera will be discussed in the tables that follow.

The larger organisms, such as Medusae, Ctenophora, *Sagitta*, and Decapod larvae, were picked out and counted before the catch was measured.

PLANKTON OF PORT ERIN BAY IN 1908.

				Copepoda.		
Date.	C.C.	Diatoms.	Dinoflag.	Adult.	Young.	Nauplii.
Jan. 4 ...	0·5	6,200	750	1,173	—	50
" 7 ...	0·75	7,950	625	1,170	—	250
" 14 ...	0·5	11,375	300	291	225	150
" 20 ...	0·7	11,500	225	909	75	450
Feb. 4 ...	0·5	15,550	200	394	200	300
" 6 ...	0·7	23,925	625	724	375	1,870
" 10 ...	0·5	3,900	300	187	—	200
" 13 ...	0·7	15,400	200	110	100	100
" 17 ...	0·3	39,350	1,000	175	—	750

Date.	C.C.	Diatoms.	Dinoflag.	Copepoda. Adult.	Copepoda. Young.	Copepoda. Nauplii.
Mar. 4 ...	0·7	32.000	300	382	—	300
.. 11 ...	0·5	13,225	150	152	75	1.000
.. 17 ...	3·0	127,500	500	3,830	1,500	15,500
.. 21 ...	3·0	94,600	250	3,126	500	5,000
Apr. 2 ...	2·5	45.250	200	4,090	3,750	8,500
.. 7 ...	1·5	64,750	400	420	—	2,000
.. 13 ...	4·5	329,450	3,100	—	1.250	37,500
.. 14 ...	3·5	305,600	1,500	410	1.000	7,000
.. 16 ...	2·5	267,750	1,000	165	500	3,000
.. 17 (c.)	5·5	88,000	—	2,490	500	500
.. 17 ...	4·5	226.000		370	500	4,000
.. 18 ...	23·5	266.000	2,500	1,280	1,000	2,000
.. 18 ...	13·5	219.300	2,500	580	—	8,000
.. 20 ...	4·5	360,750	1.000	198	100	3,000
.. 21 ...	13·5	239.500	500	1.170	500	3,500
.. 21 ...	11·0	217,750	500	1.095	500	2.500
.. 21 ...	11·0	195,000	—	1.036	500	3,000
.. 21 ...	8·5	287,000	750	1,005	500	4,000
.. 22 (c.)	6·5	64,750	—	810	500	500
.. 22 ...	7·0	589.500	—	155	500	3.000
.. 22 ...	8·0	397,500	250	128	750	2,250
.. 22 ...	9·5	460.050	1.050	186	1,500	3,750
.. 23 (c.)	3·0	70.500	—	82	—	—
.. 23 ...	7·0	674,500	1,000	21	—	—
.. 23 ...	9·5	951,000	1,000	610	—	2,000
.. 23 ...	7·5	879,000	1,000	286	—	2,000
.. 24 ...	6·5	639,000	—	165	2,000	3,000
.. 24 ...	7·0	726.700	—	200	2,500	4.000
.. 25 (c.)	6·0	97,250	—	1,200	1.000	500
.. 25 ...	7·5	1,276.200		170	150	2,000
.. 25 ...	9·0	917,400	150	2.520	2,000	4,000
.. 25 ...	8·0	878.500	150	770	2.000	4,000
.. 27 ...	8·5	1.389.100	100	620	1.100	12.000
.. 29 (c.)	8·0	127.250		2.323	3,000	100
.. 29 ...	11·5	1.775.700	300	760	500	750
May 12 ...	3·75	33,375	750	18	—	250
.. 20 ...	15·0	2.290.000	80.000	146	—	15,000
.. 26 ...	4·5	319,500	67,000	478	—	1.500
.. 28 ...	17·75	2.873.150	7,250	530	1,750	4.400
.. 30 ...	15·5	2,191,250	45.500	1.390	875	5.000
June 2 ...	6·5	1,612,500	55,000	1.285	2.500	25,000
.. 4 ...	6·25	1,795,000	135,000	3,792	10.000	25.000
.. 6 ...	3·25	583,850	48,750	325	—	—
.. 10 ...	9·5	13,250	32,750	4,314	1.000	1.500
.. 12 ...	4·5	28,125	13,375	2.863	3,750	1,000
.. 18 ...	5·5	968.375	13.250	3.333	500	7,500
.. 25 ...	4·0	1.621.000	46,000	150	1.250	2.500
.. 30 (c.)	22·0	3,640.500	50,000	8,650	10,000	4,500
July 2 ...	3·8	1,167,500	137.500	332	—	2.500
.. 7 ...	1·0	137.000	18,000	82	—	1,000
.. 14 ...	0·45	13.350	1,125	135	—	1,125
.. 21 ...	0·65	33,375	5,725	150	—	750
.. 27 ...	0·4	525	1,400	195	62	900
Aug. 5 ...	1·4	—	23.700	690	1.200	6,200
.. 5 ...	2·5	500	52,250	1,470	1,000	20,000

				Copepoda.		
Date.	C.C.	Diatoms.	Dinoflag.	Adult.	Young.	Nauplii.
Aug. 5 (w.)	1·4	—	44,250	257	300	3,750
,, 7 ...	1·0	1,050	5,950	981	200	5,000
,, 7 ...	1·0	300	8,600	2,035	700	6,800
,, 18 ...	0·5	3,100	4,400	545	300	6,400
,, 26 ...	1·4	3,000	8,700	1,245	1,800	32,100
,, 26 (w.)	0·6	150	1,025	201	200	1,000
,, 28 ...	0·1	150	330	50	60	300
,, 28 ...	0·5	250	500	175	50	1,200
,, 28 (w.)	0·3	25	325	115	50	700
,, 29 ...	0·4	25	125	101	50	450
,, 29 ...	0·3	70	170	200	10	900
Sept. 14 (c.)	2·0	2,400	100	64,470	21,000	4,800
,, 14 ...	1·5	6,800	1,280	3,545	2,400	12,000
,, 16 (c.)	19·0	2,100	—	46,600	30,000	1,300
,, 16 ...	0·6	450	200	567	500	4,000
,, 17 (c.)	10·0	200	—	16,850	7,500	750
,, 17 ...	0·5	600	100	207	225	350
,, 21 (c.)	1·5	1,360	4,000	2,870	2,260	12,400
,, 21 ...	5·5	560		4,640	1,120	240
,, 22 (c.)	4·0	1,040	—	7,972	2,000	160
,, 22 ...	1·0	4,200	1,950	1,024	500	4,600
,, 24 (c.)	6·5	400	—	7,356	1,680	160
,, 24 ...	1·5	1,650	250	1,160	500	2,800
,, 25 (c.)	5·0		—	9,155	1,920	240
,, 25 ...	2·0	1,050	400	905	1,500	5,800
,, 28 (c.)	4·8	400	—	11,740	2,700	240
,, 28 ...	0·5	900	200	609	700	4,750
,, 29 (c.)	4·7	1,200	—	9,961	4,900	1,440
,, 29 ...	0·4	375	500	231	150	980
,, 30 (c.)	3·5	1,280	—	4,609	1,760	240
,, 30 ...	0·8	1,300	3,650	913	1,400	7,700
Oct. 1 (c.)	4·0	1,920	—	5,885	3,360	1,200
,, 1 ...	0·5	2,150	1,600	727	600	3,750
,, 2 (c.)	2·5	4,200	—	7,659	5,750	700
,, 2 ...	1·0	4,300	1,900	1,029	700	2,750
,, 3 (c.)	1·7	2,960	320	4,180	2,560	1,120
,, 3 ...	0·75	10,850	850	903	600	1,500
,, 5 (c.)	1·5	5,920	160	3,761	4,000	560
,, 5 ...	1·2	15,250	800	901	2,500	5,000
,, 6 (c.)	2·5	30,400	800	2,650	2,400	6,000
,, 6 ...	2·0	2,750	—	12,560	3,500	500
,, 7 (c.)	6·0	1,700	—	9,000	9,500	300
,, 7 ...	2·2	22,400	1,200	3,365	3,800	14,600
,, 8 (c.)	9·7	2,400	—	33,970	16,000	1,000
,, 8 ...	1·8	11,600	500	2,540	5,000	4,500
,, 9 (c.)	5·0	2,800	200	12,120	7,800	500
,, 9 ...	0·4	6,800	550	344	1,500	2,000
,, 12 (c.)	14·5	600	—	39,000	40,000	6,500
,, 12 ...	1·0	7,500	1,200	684	1,000	1,800
,, 13 (c.)	6·0	3,400	1,000	19,540	13,400	1,800
,, 13 ...	3·0	41,100	5,400	1,895	1,600	4,000
,, 14 (c.)	10·5	1,500	—	35,200	38,500	3,500
,, 14 ...	0·75	2,450	200	559	650	750
,, 15 (c.)	4·0	3,600	500	16,480	12,500	2,300
,, 15 ...	1·2	54,350	3,100	527	400	3,000

				Copepoda.		
Date	C.C.	Diatoms.	Dinoflag.	Adult.	Young.	Nauplii.
Oct. 16 (c.)	3·5	1,900	100	16,500	4.500	1,200
.. 16 ...	3·0	149.300	2,700	2.880	2,100	7,500
.. 17 (c.)	3·0	1.200	240	15.455	2.000	560
.. 17 ...	1·0	30.500	1,400	468	300	3.000
,, 19 (c.)	2·2	1,700	160	14.695	3.000	560
,, 19 ...	0·4	6,200	125	285	150	100
,, 20 (c.)	3·0	1,700		11,958	3,000	500
,, 20 ...	0·4	2,675	100	457	100	225
,, 23 (c.)	5·0	400	—	15,060	11,000	1.100
,, 23 ...	0·3	1,100	—	255	75	350
.. 24 (c.)	4·0	600	—	14,240	7,000	200
,, 24 ...	0·5	2,245	100	941	625	725
.. 26 (c.)	4·5	1.000	100	16.345	4.500	1,400
.. 26 ...	0·5	3,775	425	525	325	1,000
,, 28 (c.)	5·5	5,900	200	15.100	3 400	100
,, 28 ...	0·75	3,270	120	1.077	550	300
.. 29 (c.)	5·5	2.200	500	23.780	11,000	500
,, 29 ...	0·75	2.700	150	905	990	710
Nov. 2 (c.)	4·0	3,300		19.065	18.600	300
.. 2 ...	0·8	6,830	390	899	930	300
.. 6 (c.)	3·8	4,500		3,760	3.650	150
,, 6 ...	0·2	7.730	570	305	60	660
.. 10 (c.)	3·9	5,800		5,340	3,300	100
.. 10 ...	0·2	1,670	60	160	1,500	1,200
.. 13 (c.)	2·6	7,575	75	2.794	1.400	150
,, 13 ...	0·4	6.500	1.100	301	200	1,250
,, 30 (c.)	1·8	5,120	240	4,286	950	160
,, 30 ...	0·1	1,860	390	221	30	490
Dec. 4 (c.)	1·8	14,500	—	3.925	1,800	300
.. 4 ...	0·1	1,230	510	94	30	150
,, 15 (c.)	2·3	5,600	100	5.650	1.100	100
.. 15 ...	0·1	210	270	121	30	60
.. 23 (c.)	1·9	9,030		5,722	1,700	100
.. 23 ...	0·2	330	240	261	270	240
.. 30 (c.)	3·2	5,700	—	7,650	2.500	100
.. 30 ...	0·8	(gathering accidentally lost).				

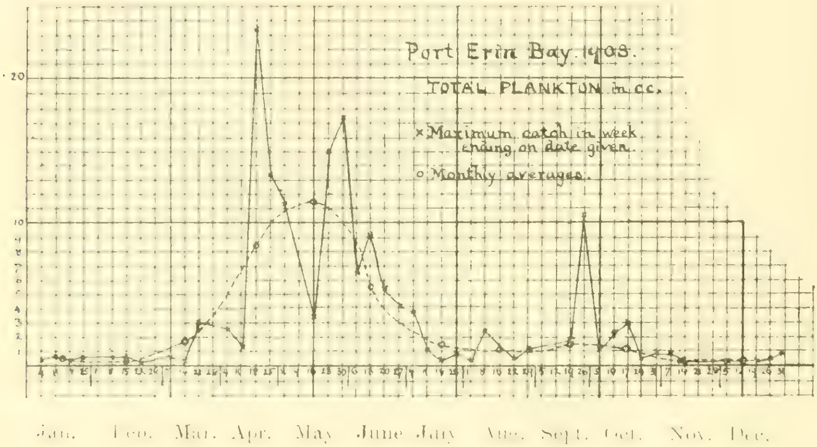
In considering the totals of the plankton catches in Port Erin Bay during 1908, we find that they are low in January and February, averaging only 0·5 c.c. per haul. The first rise is on March 17th, when the amount increases to 3 c c. per haul, and the averages remain very much at that level until about the middle of April, and then rise rapidly to 23·5 c.c on April 18th. After that there is a drop, and the amounts vary around 10 c.c. for about a month, and then run up on May 20th to 15 c.c.; on May 28th, to 17·75 c.c.; on May 30th, to 15·5 c.c. They then drop to 3·5 c.c., and vary between that and 9·5 c.c. (22 c.c.

in coarse net on June 30th) throughout June. In July the amount drops rapidly to less than 1 c.c. (0·4 c.c. on July 27) and remains low (0·1 to 2·5 c.c.) through August. The amount in September begins low, but rises suddenly on the 16th to 19 c.c. (in the coarse net—the increase being due mainly to Copepoda), while on the 17th it was 10 c.c., and on the same days the catch in the fine nets was only 0·6 and 0·5 c.c. During the remainder of the month the catch in the coarse net averaged about 6 c.c., and in the fine net 1·5 c.c. During October the range was much the same, the coarse net having 9·7 on the 8th, 14·5 on the 12th, and 10·5 c.c. on the 14th, and, apart from these exceptional hauls, averaging 4·95 c.c.; while the fine net ranged from 3 down to 0·3, and averages 1 c.c. On the whole the amounts are much lower in the second half of the month, and in November they become lower still, the coarse net descending from 4 c.c. on November 2nd to 1·8 c.c. on the 30th, and the fine from 0·8 on the 2nd to 0·1 on the 30th. Finally in December the numbers were:

Coarse net .	1·8	2·3	1·9	3·2	average 2·3
Fine net......	0·1	0·1	0·2	0·8—	average 0·3

These results are seen most clearly in the form of curves, so we give here (fig. 1) the unsmoothed zig-zag obtained by uniting the values in cubic centimetres of the maximum weekly hauls, and also the smoothed curve that passes through the monthly averages. After noticing the enormous maximum in spring and early summer (April to June) and the lesser one in late autumn (September and October), the outstanding feature of these results is the lateness of the so-called "spring" maximum this year. In 1907 (see last year's Report, pp. 105 and 173) the maximum was reached early in April, while this year it is late in May. The moderate elevation of June last year is again present this year, but is practically merged in the late spring maximum. There is again a minor elevation early in August and a much more marked maximum in the latter half of September and the first half of October, which no doubt corresponds to the autumn maximum of 1907.

Fig. 1.



WEATHER CONDITIONS.

The local plankton season has been obviously much later in 1908 than it was in 1907, and one naturally turns first to the "weather" conditions in seeking a cause. The influences that might possibly be at work are (1) the winds, tides and temperatures in the locality at the time or shortly before, and (2) factors more remote both in distance and time, such as the physical conditions in the North Atlantic. Let us enquire first into the characters of the local weather in 1908, and make such comparisons as seem possible with the records for 1907.

The Influence of Prevalent Winds.

It was shown long ago by Sir John Murray on the West Coast of Scotland that the prevailing winds, especially if they blow on or off shore for a few days at a time, have a strong effect upon the temperature and other characters of the water—driving the surface layer along and allowing deeper layers, which may be of different character, to appear on the surface behind. As the layers from different depths may be characterised by different types and quantities of plankton, it is evident that the plankton catch day by day on the surface at one spot may be influenced by the direction and intensity of the wind. Consequently it may be worth enquiring whether any relation can be established between the varying plankton catches and the weather records at Port Erin.

For the last fifteen years weekly forms recording the weather have been filled up by the Curator of the Biological Station, and for the last six years records of the sea and air temperature and of the weather have been made for the Meteorological Office, London. On these forms the direction of the wind is entered twice daily, at 9 a.m. and 3 p.m., with such a rough indication of the intensity as is given by the words "light," "fresh," "strong," and "gale."

We have assigned the values 1, 2, 3 and 4 respectively to these four terms, and in distributing the numbers of the records and their values between the sixteen points of the compass we get the results for the months of 1907 and 1908 which are shown in the accompanying tables and diagrams.*

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* For which we are indebted to George W. Herdman, B.Sc., who has kindly analysed and summarised the daily records and has constructed the diagrams.

1908	N		NNE		NE		ENE		E		ESE		SE		SSE		S		SSW		SW		WSW		W		WNW		NW		NNW		Total Intensity.
	Obs.	Int.	Obs.	Int.	Obs.	Int.	Obs.	Int.	Obs.	Int.	Obs.	Int.	Obs.	Int.	Obs.	Int.	Obs.	Int.	Obs.	Int.	Obs.	Int.	Obs.	Int.	Obs.	Int.	Obs.	Int.	Obs.	Int.	Obs.	Int.	
Jan.	3	8	2	6	3	5	—		3	3	5	9	4	5		–	8	14	3	6	9	14	3	6	9	14	5	13	4	10			113
Feb.	4	9	3	7	1	1									1	1	2	2			2	5	1	2	17	27	12	26	8	18	6	12	110
Mar.	5	11	3	5	4	8			6	6	5	8	3	3	2	3	8	11	2	4	4	7	3	5	6	12	2	4	2	2	4	9	98
Apr.	11	16	2	3	3	4	—		10	17	3	6	11	15			2	3	2	3	3	3	2	3	1	1	1	2	6	10	3	5	91
May	4	5	2	3					2	2	7	13	5	6	1	2	6	8	7	13	11	16	2	2	9	11							81
June	11	16	1	2	—	—	—	—	3	3	10	13	4	4	—		1	2	1	2	8	13	2	2	10	10	3	5	2	3	2	4	79
July	9	15	3	7		—	–	—	—		6	7					5	7	10	15	6	10			7	7	1	1	7	8	1	1	78
Aug.	6	11	5	8					5	5	6	9	1	3			2	4			3	4	4	6	16	29	8	12			2	2	93
Sept	5	10	3	3	—	—	—	—	1	2	7	10	1	1	2	2	10	14	5	10	6	13	2	3	10	15	1	1	1	3	5	10	97
Oct.	—	—			–				3	5	19	30	17	23	1	2	5	6	8	9			2	4	2	4	1	1	—		—	—	84
Nov.	4	9	—	—	—	—	—	—	2	4	5	6	10	15	2	2	6	9	2	4	7	13	3	5	10	25	3	8	3	7	2	5	112
Dec.	1	3		—	—				4	5	7	12	10	22	1	2	9	14	5	10	6	8	2	5	8	13	3	8	2	4	2	7	113
	63	113	24	44	11	18	—	–	39	52	80	123	66	97	10	14	64	94	45	76	65	106	26	43	105	168	40	81	35	65	27	55	1,149

1907	N		NNE		NE		ENE		E		ESE		SE		SSE		S		SSW		SW		WSW		W		WNW		NW		NNW		Total Intensity.
	Obs.	Int.	Obs.	Int.	Obs.	Int.	Obs.	Int.	Obs.	Int.	Obs.	Int.	Obs.	Int.	Obs.	Int.	Obs.	Int.	Obs.	Int.	Obs.	Int.	Obs.	Int.	Obs.	Int.	Obs.	Int.	Obs.	Int.	Obs.	Int.	
Jan.	4	8	1	2	1	1	1	2	3	5	2	3	1	1	0	0	5	7	2	4	4	4	5	5	21	35	8	14	3	6	1	1	98
Feb.	4	7	5	10	2	2	—	—	1	1	3	4	2	2	1	1	3	3	4	6	10	19	1	2	10	16	6	12	2	5	1	3	93
Mar.	3	3	—	—	—	—	—	—	3	3	6	7	—	—	1	1	2	2	8	10	12	21	3	6	9	18	11	25	2	6	1	1	103
Apr.	8	9	5	7	1	1	1	2	7	10	4	7	4	5	—	—	3	4	4	7	5	9	2	3	10	13	—	—	2	3	2	2	82
May	5	5	4	7	1	1	—	—	9	14	7	11	6	11	2	4	2	4	6	10	3	6	2	4	7	12	1	3	1	2	4	5	99
June	2	2	2	3	—	—	—	—	1	2	2	3	1	2	—	—	10	14	5	9	9	16	3	4	8	14	9	14	4	7	1	1	91
July	6	7	—	—	—	—	—	—	1	2	8	12	5	5	1	1	4	7	1	2	2	2	6	7	12	11	5	5	1	6	1	1	71
Aug.	3	4	—	—	—	—	—	—							1	1	3	6	2	3	8	11	8	10	23	35	5	7	5	9	2	2	88
Sept	1	1	1	1	—	—	—	—	2	2	15	20	4	4	—	—	3	3	4	4	2	3	2	4	12	15	5	6	—	—	1	1	64
Oct.	3	5	2	4	4	8	—	—	7	9	11	20	3	4	2	2	5	11	2	5	8	13	3	4	5	7	2	3	2	4	2	3	102
Nov.	3	3	1	1	3	4	2	2	5	5	8	18	4	7	1	1	—	—	6	10	7	16	1	2	6	10	4	8	5	11	4	5	103
Dec.	2	3	—	—	—	—	—	—	4	5	4	9	8	27	2	4	5	10	4	7	6	9	5	10	11	24	4	11	2	2	1	3	124
	44	57	21	35	12	17	4	6	43	58	70	114	38	68	11	15	45	71	48	77	72	129	36	61	113	213	52	108	29	61	21	28	1,118

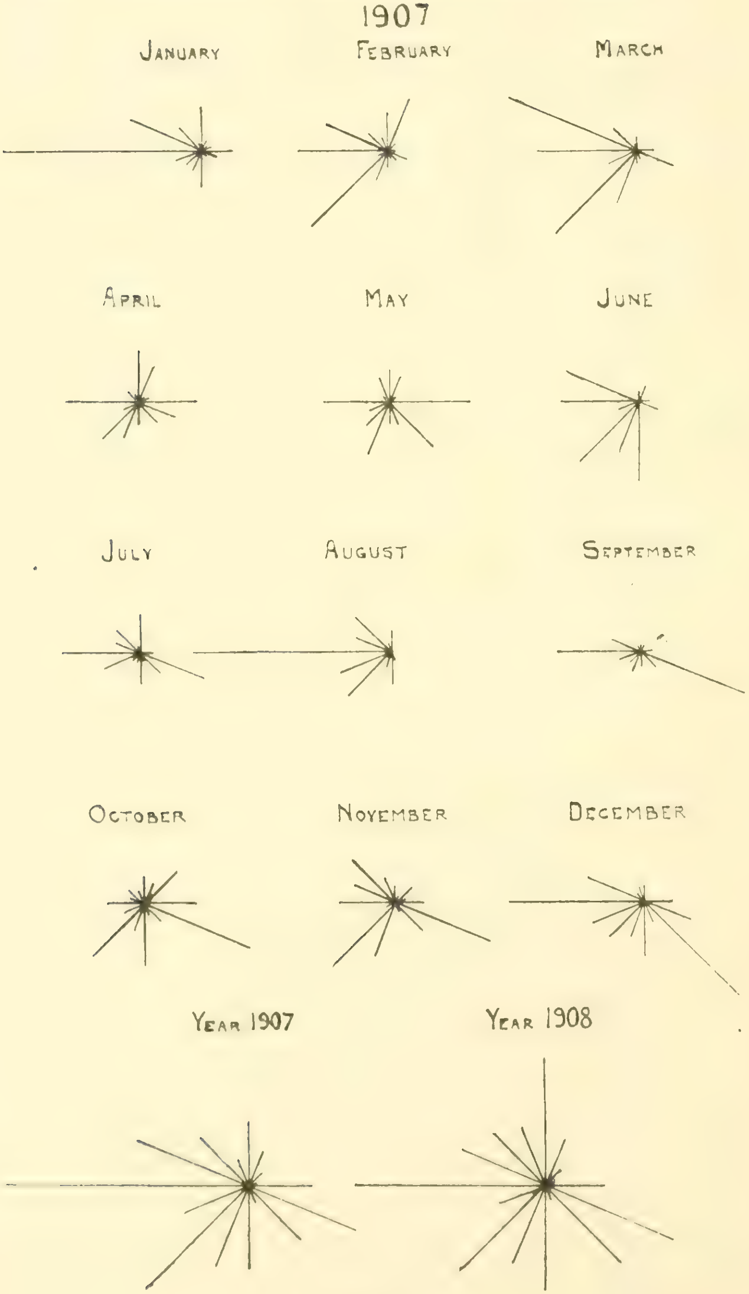

1907
January
February
March
April
May
June
July
August
September
October
November
December
Year 1907
Year 1908

Fig. 2.

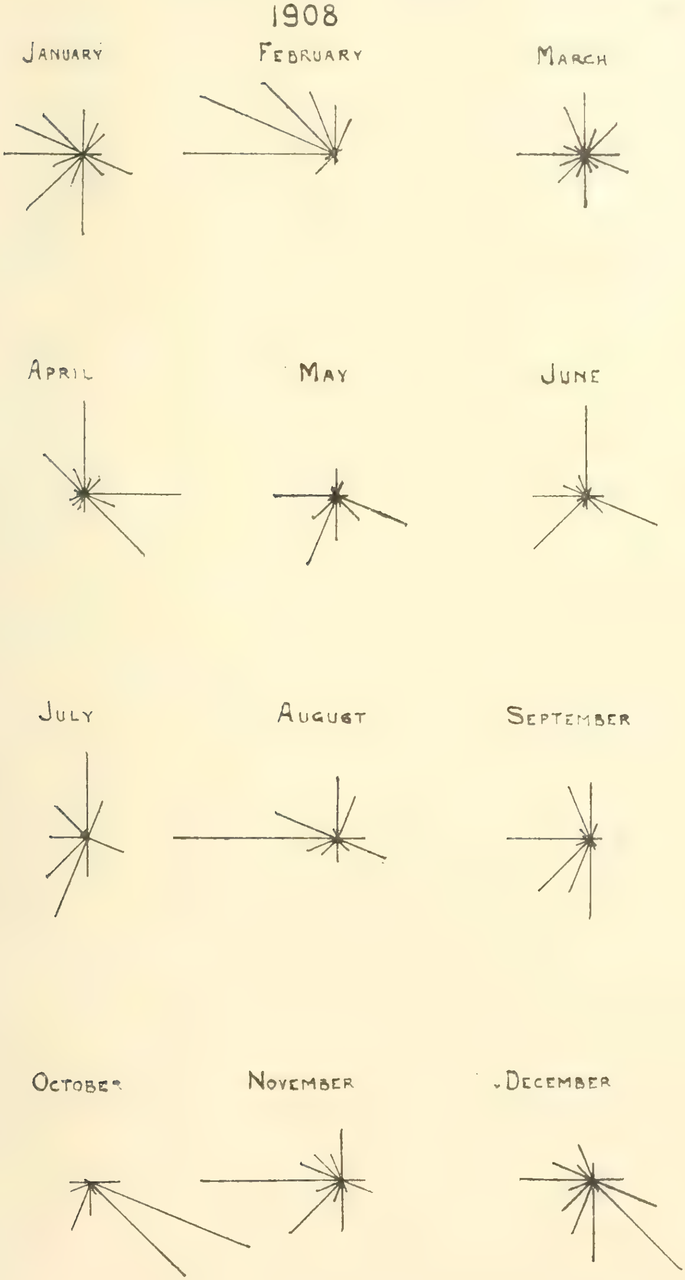

1908
January
February
March
April
May
June
July
August
September
October
November
December

Fig. 3.

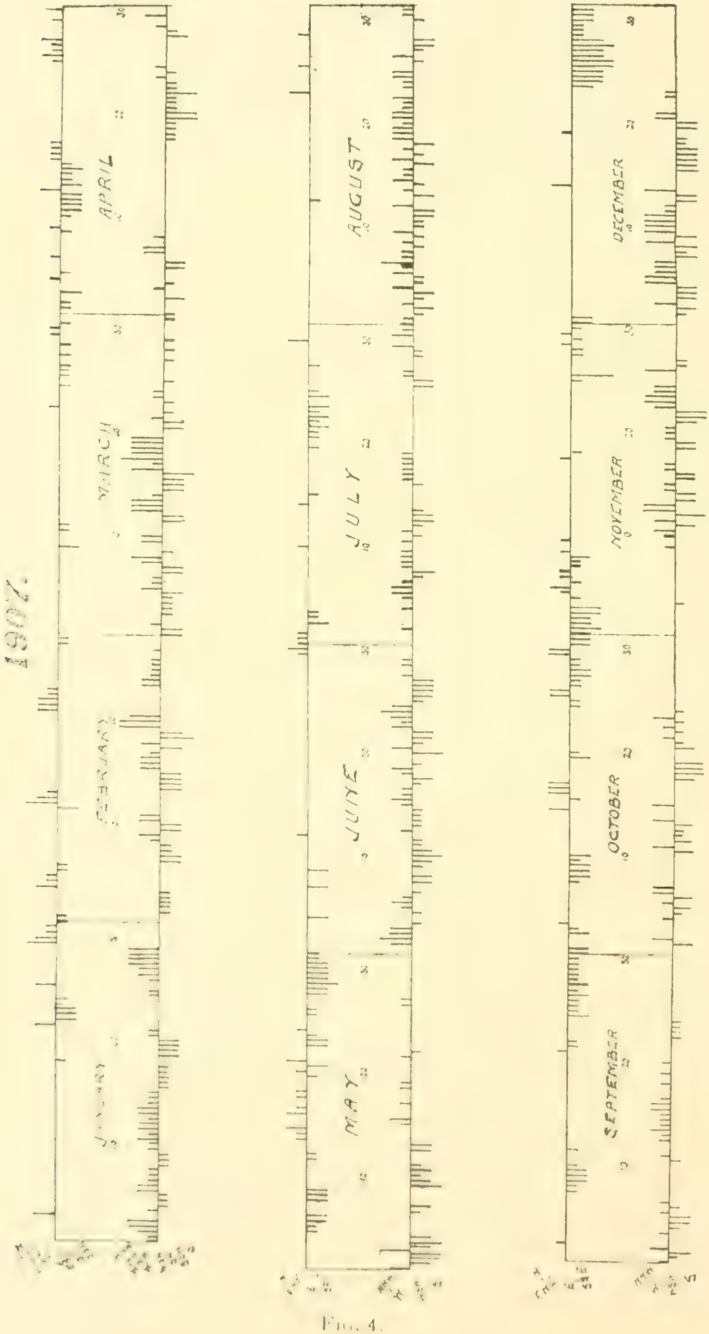

1907.
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER

Fig. 4.

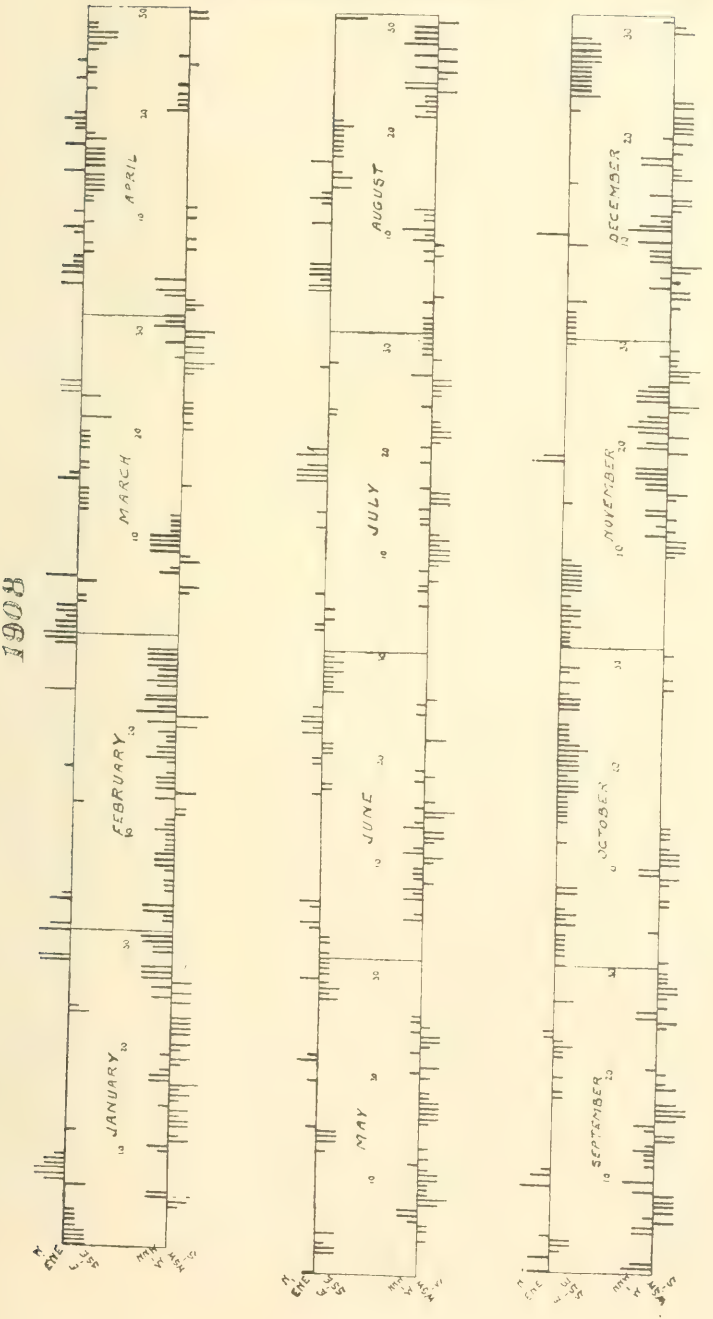

1908
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
10
20
30
N.
ENE

FIG. 5.

We have examined the records of the two last years, (1) as these are the years in which the plankton has been most carefully and fully collected at Port Erin, and (2) in order to have the results for a second year to compare with those of the one chiefly under consideration.

In 1908, no observations were recorded under E.N.E.; and the maximum number (one-seventh of the total), with maximum intensity (one-seventh of the total), were under W. In that year the following four are markedly stronger than the rest:—N., E.S.E., S.W., and W., and the following three are as markedly weaker:—N.E., E.N.E., and S.S.E. In January and March the records show wind well distributed round the compass, but February, April, May, September and October show half the compass with almost no records. The most pronounced winds are the W. and W.N.W. in February, the W. in August, the E.S.E. and S.E. in October, and the W. in November.

In 1907, there was no point without any observations, and the maximum number (one-sixth of total) with maximum intensity (one-sixth of total) were under W. The highest records were under E.S.E., S.W., W., and W.N.W., and the lowest were under N.E., E.N.E., and S.S.E. June, August and September show half the compass with almost no records. The most pronounced winds were the W. in January, August and December, the W.N.W. in March, the E.S.E. in September and October, and the S.E. in December.

Examination of the tables, or of the diagrams for the two years 1907 and 1908 taken together, shows that there are four points—E.N.E., S.S.E., W.S.W., and N.N.W. which are weak in intensity as well as in number of observations, and that consequently the year's wind appears naturally to be divided into four blocks separated by these weak points (see figs. 2 and 3):—

(1) There are the north-easterly winds, the due north being both the most frequent and most intense. This is most marked in April and July.

(2) There are the south-easterly winds, the E.S.E. and S.E. being the most important. Their intensity is about double that of the north-easterly block. They are prevalent in spring and in the last quarter of the year, and are almost absent in February and again in August.

(3) There are the south-westerly winds, of which S. and S.W. are the strongest, and these have a still higher total intensity than the last. These occur throughout the whole year, but the distribution is irregular Whereas in 1907 February and March show high intensities, in 1908 they show low, and September, which is the lowest for 1907, is amongst the highest for 1908.

(4) There are the north-westerly winds. The records of W. are more frequent than those of any other of the 16 points of the compass, and amount to about one-sixth of the total number of observations. The intensity of the W. wind also is high, and August is the month in which it is highest. The other directions in this block, viz., W.N.W., N.W. and N.N.W., are recorded chiefly early in the year and have a high intensity. The total wind in this block amounts to fully one-third of that round the 16 points of the compass.

Now easterly to south-easterly winds (2) at Port Erin blow out of the bay—often with considerable force—and outside the bay they blow off shore, and so will carry the surface waters and their contained plankton out to sea and allow the deeper layers, with any plankton that may be characteristic of these, to rise to the surface near the land. Such movements, however, will be more or less at right angles to the tidal streams, which run strongly along the shore from the Calf Island towards Contrary

Head during the ebb, and towards the south past Port Erin when flowing, and will thus no doubt be somewhat affected both in direction and amount. On the other hand, the westerly and north-westerly winds (4) blow on shore, bringing in the surface plankton from further out, and possibly allowing deeper layers of water and plankton to well up out in the middle of the channel where the depth is relatively great. The southerly and south-westerly winds (3) blow up channel, frequently with a heavy sea, and would tend to bring the plankton from St. George's Channel into our district. On reaching the shallower irregular rocky bottom off the south end of the Isle of Man, where the tides run strong, this water may very probably be so diverted and churned up as to cause vertical movements, bringing deeper layers to the surface in the neighbourhood of the Calf Island. It is here that, on various occasions, we have obtained unusually large catches of zoo-plankton. The last of our groups of winds, the north-easterly, are probably those that have least effect on the water and its contained plankton off Port Erin. Any effect will probably be much the same as that caused by the easterly group, but less in amount—and blowing off-shore from the south end of the island may cause deeper layers of water to rise to the surface close to land. Here again any such movements will probably be modified by the strong tides running round the Calf Island.

In figs. 4 and 5 the occurrence and intensity of these four groups of prevalent winds are shown as lines of varying length on each side of two datum axes for each month in the years 1907 and 1908, so that their proportional distribution may be traced day by day through the months—each recorded observation being plotted. The upper datum axis for each month has from N. to E.N.E.

plotted above and from E. to S.S.E. below, while the lower axis has from N.N.W. to W. above and from W.S.W. to S. below. The intensity of the wind at each observation is shown by the length to which the line is plotted, one unit signifying "light," two "fresh," three "strong," and four "a gale." A spell of calms, or a storm, a tract of continuous winds from one direction, or the shifting of the wind from one quarter to another can all be readily traced by the eye on these diagrams. For example, the south-easterly storm about Christmas 1907, the long calm in the easterly quarter from June to August 1907, and the changing of a light N.E. wind in the morning, to S.E. in the afternoon are noticeable.

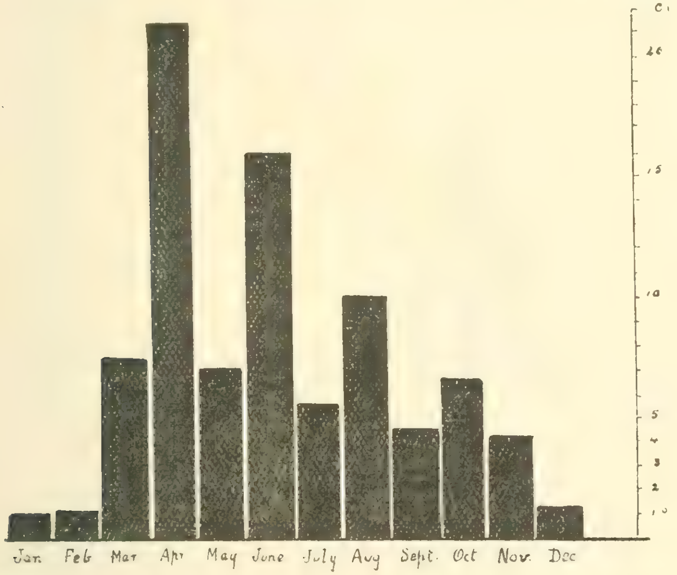


Fig. 6. Diagram showing average haul of Plankton per month in 1907.

Turning now to the plankton records for these two years, the monthly averages as shown in the two diagrams figs. 6 and 7 will be useful for comparison with the "star"-figures of the wind for the same months. The great difference in the position of the spring maximum of plankton in these two years will be appreciated when it is stated that in 1907 the catch rose to 14·5 c.c. on March 27th, to 31 c.c. on April 2nd, and to 42·5 c.c. on April 3rd; while in 1908 it was only 2·5 on April 2nd, 23·5 on April 18th, and did not reach any higher level. It will be noticed on the weather diagrams that there were distinctly more westerly and south-westerly winds in February, March and April, 1907, and more from the north and east in the same months of 1908.

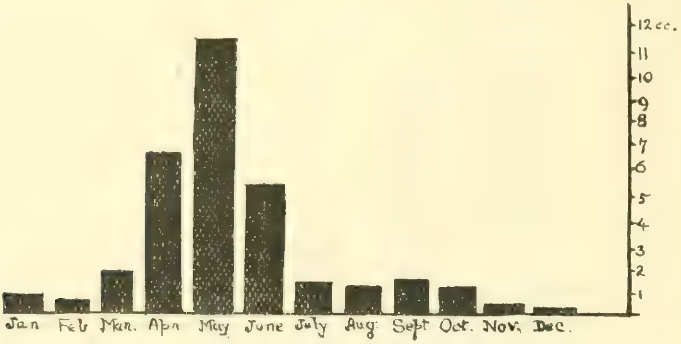


Fig. 7. Diagram showing average haul of Plankton per month in 1908.

Beginning with March, probably the critical time in the history of the spring plankton, the following contrasts are noticed on the diagrams:—

	1907.		1908.	
	Catch in c.c.	Prevalent Winds.	Catch in c.c.	Prevalent Winds.
March ...	7·5	S.W.	1·8	all directions.
April ...	21·5	W. and all directions	6·7	N. and E. and S.E.
May ..	7·0	more Easterly.	11·3	more S.W.
June ...	16·0	more S.W.	5·6	more S.E.
July ...	5·5	more S.E. and W	1·25	more S.W. and N.
August	10·0	more W. and S.W.	1·2	more W. and N. and E.
Sept. ...	4·5	more S.E.	3·8	more S. and S.W.
Oct. ...	6·5	more S.W. and S.	3·0	more S.E.
Nov. ...	4·0	more S.E.	1·8	more W.
Dec. ...	1·2	more S.E	1·3	more S.E.

From this table it appears that in March and April the larger catches are associated with south-westerly winds, and in May, 1908, we again see a much larger catch with S.W. winds and a smaller with easterly. Other instances may be noticed. On the whole, it seems that easterly winds blowing off shore are associated with smaller plankton catches inside the bay.

On looking into the weather and plankton records for individual days we find some cases that support this view, along with others that appear opposed to it. This is only to be expected, as even if prevalent winds have an important influence, the other factors in the case will no doubt affect the results markedly on occasions.

During part of one week at the end of the year (1908) the following gatherings were taken across Port Erin Bay:—

Wed., Dec. 30th, E.S.E. to S., fresh; Coarse net 3·2 and fine net 0·8 = 4 c.c.
Fri., Jan. 1st, S.W. to W.S.W., light; Coarse net 2·4 and fine net 0·6 = 3 c.c.
Sat., Jan. 2nd, W.S.W., light; Coarse net 1·7 and fine net 0·6 = 2·3 c.c.

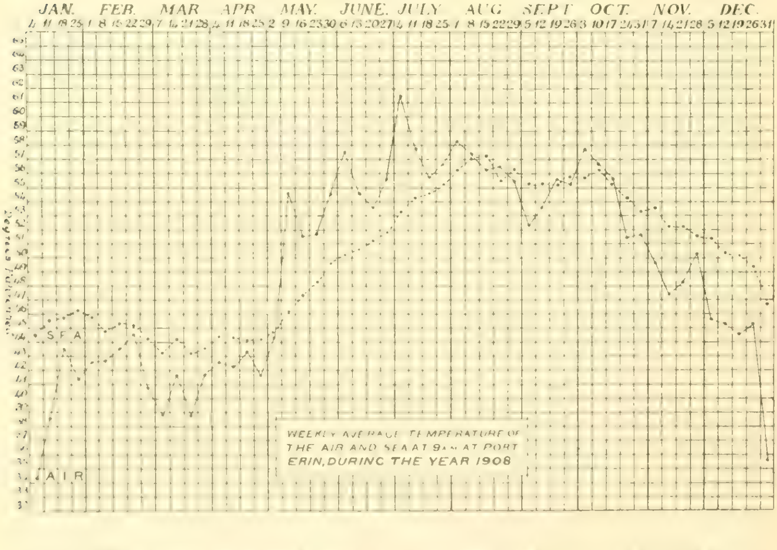
These show a gradual fall in the amount of the catch, and during that time the wind was working round from East of South to nearly West.

At the beginning of the following week the catch was:—Monday, January 4th, coarse net 4·0 and fine net 1·0 = 5 c.c., a considerable rise, with the wind W.S.W. to S.S.W., light. On these occasions any effect due to wind may possibly have been masked by other factors; and in any case the quantities dealt with are small. We would not attach much importance to either correspondence or diversity in the case of small quantities or of individual catches.

SEA-TEMPERATURES.

The dotted line in the accompanying figure shows the curve for the sea-temperatures in Port Erin Bay during

1908. It shows very clearly the way in which the temperature of the sea lags behind that of the air, being higher in winter and lower in the height of summer. On comparing with the curve for 1907 we find that in 1908 the temperature was lower, and more uniformly so, during the critical period of March and April. Then again the curve does not rise so high in June and July; and, on the other hand, in October and November the temperature is rather higher this year. The lower sea-temperatures in March and April may possibly have some relation to the undoubted lateness of the vernal plankton maxima, as compared with 1907.



WEEKLY AVERAGE TEMPERATURE OF THE AIR AND SEA AT 9 A.M. AT PORT ERIN, DURING THE YEAR 1908

The sea-temperatures to the west of the Isle of Man are still insufficiently known. In the present volume Mr. J. Johnstone has an interesting article on the temperatures in the Irish Sea, which deals chiefly, however, with the shallow-water area to the east of the Isle of Man, where nearly all observations in the past have been taken. The lines along which temperatures have been taken during the last three years on the hydrographic cruises of the Lancashire Fisheries steamer are (1) from Holyhead to the Calf Island, (2) from the Calf Island to the Piel Gas Buoy near Barrow (along latitude 54° N.), and (3) from the Piel Gas Buoy to Maughold Head in the Isle of Man. This last line was given up after the first year's work, and a new line has been added this year from the Calf Island to the Liverpool North-west Lightship. In addition various series of observations have been made in the Welsh bays further to the south; and on one occasion lately temperatures were taken in the deep water off the Mull of Galloway.

The Irish Fisheries Authorities have taken temperatures in the past from the Calf Island across towards Ireland and along several lines to the south of that from the Irish coast eastwards across the Channel. During this present winter it is understood that the new Irish Fisheries steamer has started a series of fresh lines of observing stations that will traverse the sea-area between the Isle of Man and Ireland at several different levels. These series will no doubt eventually give much needed information as to the physical conditions in the deep western channel, which differs so markedly in conformation from the shallow eastern half of the Irish Sea in which the Lancashire observations have been taken. In the meantime, as nothing has been published bearing on the deep-water area north of the Calf and west of the Isle of Man, it may be of interest to record the sea-temperatures taken on board the "Ladybird" during her work outside Port Erin in the spring and summer of 1908. Mr. Harold Drew, now of Plymouth, was on the yacht during the summer, and assisted in taking the following series of temperature observations.

In April, the following surface observations were taken, with the centigrade standard thermometers supplied by the Central International Laboratory at Christiania :—

Apr.	13	Stat.	I., 5 miles off Bradda Head	Surf. = 6·8°C.
,,	14	,,	,, ,,	Surf. = 6·8°C.
,,	15	,,	III., 1 mile off Niarbyl	Surf. = 7°C.
,,	16	,,	I. and II., 5 and 10 miles off Bradda Head	Surf. = 6·8°C.
,,	17	,,	,, ,, ,,	Surf. = 6·9°C.
,,	20	,,	III., 2 miles off Niarbyl	Surf. = 6·8°C.
,,	22	,,	I. and II., 5 and 10 miles off Bradda Head	Surf. = 6·9°C.
,,	23	,,	III., 1 mile off Niarbyl	Surf. = 6·6°C.
,,	27	,,	I. and II., 5 and 10 miles off Bradda Head	Surf. = 6·85°C.
,,	29	,,	III., 1 mile off Niarbyl	Surf. = 7°C.

In August and September, surface observations were taken with the same thermometers, as follows:—

Aug.	8	Stat.	II., 10 miles off Bradda Head	Surf. = 13·91°C.
,,	10	,,	I., 5 miles off Bradda Head	Surf. = 13·91°C.
,,	12	,,	III. (a.m.), 2 miles off land	Surf. = 13·83°C.
,,	12	,,	I., 5 miles off land	Surf. = 13·62°C.
,,	12	,,	III. (p.m.), 1 mile off Niarbyl	Surf. = 14·12°C.
,,	13	,,	I., 5 miles off land	Surf. = 13·69°C.
,,	13	,,	III., 1 mile off land	Surf. = 13·74°C.
,,	14		(17 surface observations round Island)	= 13·13° to 14·49°C.
,,	15		(5 surface observations up West Coast)	= 13·05° to 14·04°C.
,,	17	Stat.	I. (a.m.), 5 miles off Bradda Head	Surf. = 13·72°C.
,,	17	,,	II., 10 miles off Bradda Head	Surf. = 13·52°C.
,,	17		Mid.-Channel, Stat. A, 13 miles off Bradda Head	Surf. = 13·83°C.
,,	17		Mid.-Channel Stat. B, 14 miles off Bradda Head	Surf. = 14·32°C.
,,	17		Stat. I. (p.m.), 5 miles off Bradda Head	Surf. = 14·07°C.
,,	18	Stat.	I. 5 miles off land	Surf. = 13·31°C.
,,	18	,,	III., 2 miles off land	Surf. = 13·10°C.
,,	19	,,	I., 5 miles off land	Surf. = 13·51°C.
,,	19	,,	V., 1 mile off land	Surf. = 13·05°C.
,,	20	,,	I., 5 miles off land	Surf. = 13·52°C.
,,	20	,,	III., 2 miles off land	Surf. = 13·41°C.
,,	21	,,	I., 5 miles off land	Surf. = 13·65°C.
,,	21	,,	IV., close to Calf Island	Surf. = 13·25°C.
,,	22	,,	I., 5 miles off land	Surf. = 13·32°C.
,,	22	,,	III., 2 miles off land	Surf. = 13·60°C.
,,	24	,,	I., 5 miles off land	Surf. = 13·4°C.
,,	24	—	8 miles off land	Surf. = 13·38°C.
,,	24	—	11 miles off land	Surf. = 13·39°C.
,,	24		Mid. Channel Stat. A. 13 miles off Bradda Head	Surf. = 13·35°C.
,,	26		Stat. I., 5 miles off land	Surf. = 13·38°C.
,,	28		Off Life-boat slip, Port Erin Bay	Surf. = 13·85°C.
,,	28		Off Buoy, at entrance to Bay	Surf = 13·50°C.
,,	31		Stat. I., 5 miles off land	Surf. = 13·10°C.
Sept.	11		Stat. III., 2 miles off land	Surf. = 12·85°C.
,,	11		(6 surface observations round South of Island)	= 12·8° to 13·1°C.
,,	12		Stat. II., 10 miles off land	Surf. = 12·9°C.
,,	12		Mid. Channel, Stat. A., 13 miles off land	Surf. = 12·6°C.
,,	12		Stat. I., 5 miles off land	Surf. = 12·9°C.
,,	15	,,	I., 5 miles off land	Surf. = 12·9°C.
,,	19	,,	III., 2 miles off land	Surf. = 13·2°C.

On August 14th, we took a series of surface temperatures around the Island (see large figures in circles on chart, fig. 9), as follows:—

(1)	10.30 a.m., off Spanish Head	13·22°C.
(2)	10.50 a.m., Bay-ny-Carrickey	13·13°C.
(3)	11.10 a.m., off Langness	13·13°C.
(4)	11.17 a.m., off Langness (in tidal race) ...	13·53°C.
(5)	11.55 a.m., off Santon Point	13·90°C.
(6)	12.20 p.m., off Douglas Head	14·00°C.
(7)	12.50 p.m., off Clay Head	14·06°C.
(8)	1.20 p.m., off Laxey	14·49°C.
(9)	2.0 p.m., off Maughold Head	14·23°C.
(10)	2.25 p.m., off Ramsey Bay	14·12°C.
(11)	2.45 p.m., East of Pt. of Ayre	14·19°C.
(12)	2.55 p.m., West of Pt. of Ayre	14·21°C.
(13)	3.30 p.m., Jurby Bay	13·72°C.
(14)	4.10 p.m., off Kirkmichael	13·38°C.
(15)	5.10 p.m., off Peel Head	13·95°C.
(16)	5.40 p.m., off Niarbyl	13·71°C.
(17)	6.5 p.m., off Bradda	13·21°C.

On this occasion the sea was smooth, the sun bright, the wind of strength 1 to 2, N., by E., and high water was at 12.50 p.m. when the observation (7) off Clay Head, north of Douglas, was taken, so that we carried the tidal stream with us (either flowing or ebbing) nearly all the way round the island. It will be noticed that with this rising tide flowing northwards the coldest water (13·13°) was at the south end of the island off Port St. Mary and Castletown, and that it got steadily warmer going north until the highest point (14·49°) was reached off Laxey between high water, by the shore (at Clay Head) and the "head of the tide" at Maughold. From this point it fell steadily round the north and west sides of the island, with slight rises at Point of Ayre (where two currents join) and again off Peel (where the tides from the north and south meet), until at Bradda Head it reaches 13·21°—very nearly the temperature with which we started at Spanish Head.

It must not be supposed, however, that we attach much hydrographic importance to a single series of surface temperatures such as these, unsupported by salinities and uncorrected by further observations on neighbouring days under other conditions of weather.

On August 15th we were trawling on the Ballaugh Bank, and took a series of observations up to a point ten miles north of Peel, as follows:—

(1) Off Peel Head. Surface = 13·70 C.
(2) 2 miles N. of Peel. Surface = 13·55 C.
(3) 3½ miles N. of Peel. Surface = 13·05 C.
(4) 8½ miles N. of Peel. Surface = 13·81 C.
(5) 10 miles N. of Peel, Surface = 14·04°C.
10 miles N. of Peel, at 2½ fathoms 12·87 C.
10 miles N. of Peel, at 6 fathoms 12·32°C.
10 miles N. of Peel, at 13 fathoms 11·39°C.
10 miles N. of Peel, at 22 fathoms (bottom) 11·39°C.

The sea was smooth, sun bright, wind E., of strength 1 to 2. It is evident that, on this day, at this point ten miles N. of Peel the water was warmest on the surface, and was fully two and a half degrees Centigrade lower at 13 to 22 fathoms.

On September 11th, surface temperatures and samples of the sea-water were taken at the following points between Port St. Mary and Niarbyl:—

(1)	10.20 a.m.,	1 mile off Port St. Mary	13 C.
(2)	10.50 ,,	off the Chasms	13 C.
(3)	11.0 ,,	S. of Calf Sound (ebb northward beginning)	13·1 C.
(4)	11.11 ,,	N. of Calf Sound	12·8°C.
(5)	11.30 ,,	off Bradda Head	13 C.
(6)	12 (noon)	off Niarbyl	12·85 C.

The sea was moderate, with a light N.N.E. wind and bright sunshine—after some days of rough weather.

The surface water was on this occasion (September 11th) distinctly colder than we had found it on either August 14th or August 15th in the same neighbourhood. In addition to the occasion on August 15th, given above, when sea-temperatures were taken at intervals from the surface to the bottom, there were four other vertical series of temperatures taken during August and September in the deepest part of the channel (64 to 74 fathoms), between Port Erin and Ireland, as follows:

(1) August 17th, Mid-Channel Station A, 13 miles N.W. by N. ½ N. of Bradda Head. Sounding 64 fathoms, mud. Temperatures with Negretti and Zambra's deep sea reversing thermometer:

At surface ...	= 57·3°F.
,, 10 fathoms	= 56·2°F.
,, 20 ,,	= 55·1°F.
,, 40 ,,	= 56·2°F.
,, 60 ,,	= 60°F.

(2) August 17th, Mid-Channel Station B, 14 miles N.W. of Bradda Head. Sounding 74 fathoms. Temperatures with reversing thermometer:

At surface	= 58·2°F.
,, 10 fathoms	= 57·3°F.
,, 20 ,,	= 57·1°F.
,, 30 ,,	= 56·5°F.
,, 50 ,,	= 56·5°F.
,, 72 ,,	= 62·6°F.

(3) August 24th, Mid-Channel Station A, 13 miles N.W. of Bradda Head. Sounding 64 fathoms, mud. Temperatures with reversing thermometer:—

At surface	= 56·2°F.	corrected to	*13·2°C.
,, 10 fathoms	= 56·8°F.	,,	13·5°C.
,, 20 ,,	= 56·0°F.	,,	13·1°C.
,, 30 ,,	= 54·7°F.	,,	12·4°C.
,, 40 ,,	= 54·0°F.	,,	12·0°C.
,, 50 ,,	= 57·2°F.	,,	13·7°C.
,, 62 ,,	= 53·3°F.	,,	11·6°C.

(4) September 12th, Mid-Channel Station B, 14 miles N.W. of Bradda Head. Sounding 74 fathoms, mud. Temperatures with reversing thermometer:—

At surface	= 55·0°F.	corrected to	12·6°C.
,, 10 fathoms	= 55·0°F.	,,	12·6°C.
,, 20 ,,	= 55·0°F.	,,	12·6°C.
,, 30 ,,	= 55·0°F.	,,	12·6°C.
,, 40 ,,	= 54·5°F.	,,	12·3°C.
,, 50 ,,	= 54·0°F.	,,	12·0°C.
,, 60 ,,	= 53·0°F. (or (?) 57·0°F.)		11·5°C.
,, 70 ,,	= 51·0°F.	,,	10·4°C.

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* On International Standard Thermometer. (Mr. Drew.)

On the last of these occasions (September 12th), when the thermometer came up from 60 fathoms it read 57° F. Thinking that this might be a mistake it was lowered to the depth again, and this time it read 53° F., and the record was corrected to that figure: but it is just possible that the former temperature may have been correct for a very limited layer of water into which the thermometer had passed on the first occasion, since it will be noticed that in all four of these series of temperatures in mid-channel there is apparently an indication of a warmer layer near the bottom lying underneath colder water—on August 17th (A) at 60 fathoms and (B) at 72 fathoms, on August 24th at 50 fathoms, and on September 12th, if the first reading was correct, at 60 fathoms. It is important to remember that all of these four series were taken in that central region of the western part of the Irish Sea which is marked on the charts and in the "Sailing Directions" as having no perceptible tidal stream and where the deeper layers of water are probably comparatively little disturbed, and are certainly not churned up at every tide as seems to be the case in the shallow water between the Isle of Man and England or Wales. The deep water to the west of Port Erin still awaits investigation as to its physical conditions, its movements, if any, and its possible connection with oceanic water outside the Irish Sea; and the comparatively few and rather sporadic temperatures recorded above have been given chiefly for the purpose of showing how little has yet been done, but how interesting in several ways this deep western channel may prove to be.

Mr. Drew took samples of the sea-water from each position where serial temperatures were observed, and he has worked out the salinities, but considers that the results are not sufficiently complete to justify publication.

He makes, however, the following remarks upon them which may be of use in connection with future work:—

“You will notice that there appears to be a complete reversal of conditions between August 24th and September 12th. On August 24th, the water of lowest salinity (chlorine = 34·08) is at 62 fathoms, and the water of highest salinity (chlorine = 34·12) is at 20 fathoms, and from 20 fathoms to the surface there is a slight decrease, but the general condition may be taken as high salinity above and low salinity below. On September 12th, the water of highest salinity (chlorine = 34·07) is below and of low salinity (chlorine = 33·96) above. In this case there appears to have been an inflow of cold, high salinity water along the bottom. The difference between the temperatures of the bottom samples is well marked, and is much more than would be accounted for by the difference of the surface temperatures. I think the hydrographical conditions in the neighbourhood would be of great interest if more frequent observations could be taken.

“It would seem improbable from these results that that complete mixing of the water occurs which I understand has been found between the Isle of Man and England—there is a very definite division of the water into layers which probably correspond to inflows of water along the deep channel: I should think that current measurement work in the same locality might produce very interesting results.”

Tides in the Irish Sea around the Isle of Man.

Amongst the factors that may have an effect on the variations of the plankton in space, time and quantity, the tidal streams still remain to be considered.

The main lines of the tidal currents in the Irish Sea have been known for many years from the Admiralty publications* (based upon Captain Beechey's well-known observations in the Phil. Trans. of the Royal Society), and were summarised by one of us some years ago somewhat as follows:

The tidal wave coming in from the open Atlantic reaches the Irish Sea round both ends of Ireland (see Chart, fig. 8), but mainly round the south. The northern entrance is narrower, and admits only a comparatively small proportion of the total volume of water. For nearly six hours after low-water, at, say Liverpool, two tidal streams pour into the Irish Sea, the one from the north of Ireland, through the North Channel, and the other, the larger, from the southward, through St. George's Channel. Parts of the two streams meet and combine to the west of the Isle of Man, where there is a large elliptical area, about 20 miles in diameter, and reaching from off Port Erin towards Carlingford, over which there is no perceptible tidal stream,† the level of the water merely rising and falling with the tide. The remaining portions of the two tidal streams pass to the east of the Isle of Man, and eventually meet along a line, "the head of the tide," extending from Maughold Head into Morecambe Bay. During the ebb the above currents are practically reversed, but in running out the southern current is found to bear more over towards the Irish coast.

The tide is high at Liverpool about eight hours after the same wave reaches Bristol, and an hour and twelve

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* See the Charts, the Admiralty Sailing Directions for the West Coast of England, and for Ireland, and "The Tidal Streams of the English and Irish Channels" (Hydrographic Office, Admiralty, London, May, 1899). This information was summarised, as stated above, in Herdman and Dawson, "Fishes and Fisheries of the Irish Sea" (G. Philip & Co., London, 1902).

† The existence of such an area is, however, disputed by the fishermen at Port Erin, who state that even out in the channel there is sufficient tide running to carry the floats of their nets and lines under water.

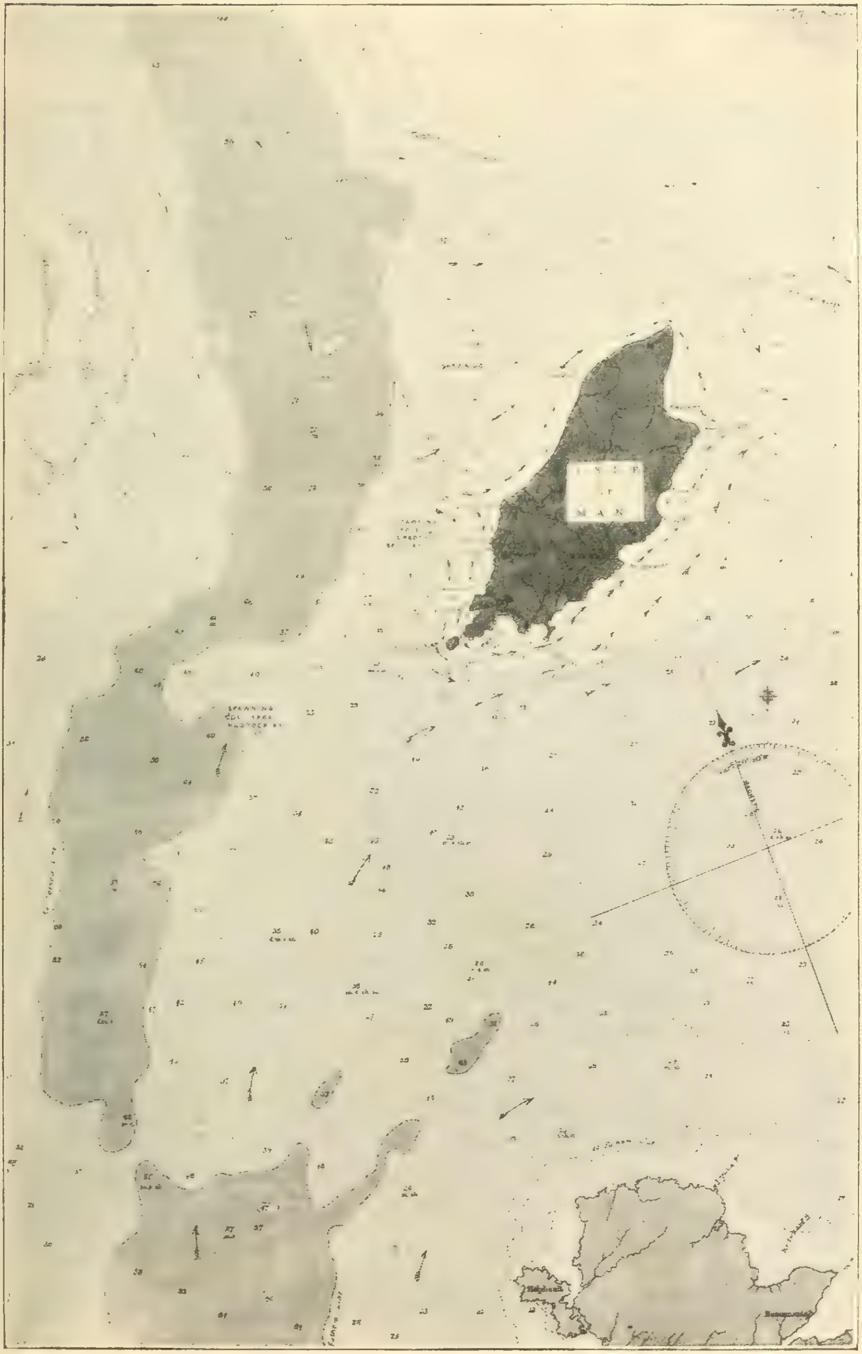

FIG. 8. Course of Flood tide in Irish Sea round Isle of Man.
Scale: 20 sea miles = 1½ inches.

minutes later than it is at Holyhead. For the south end of the Isle of Man about 14 minutes has to be subtracted from the Liverpool time, and high tide at the Isle of Man is synchronous with that at Dover. The tidal rise and fall at Liverpool varies from about 11 feet at low neaps, to 31 feet at high springs. All the highest tides in our district occur about midday and midnight, consequently the lowest spring tides, which are the best opportunities that the naturalist has for collecting marine animals on the shore, are about 6 a.m. and 6 p.m., an arrangement which allows of two tides a day being worked in summer, but prevents, on account of darkness, a low spring tide from being seen during the winter half of the year.

There is some reason to believe that, as a result of the general drift of the surface waters of the Atlantic, and the shape and direction of the openings to the Irish Sea, more water passes out by the North Channel than enters that way, and more water enters by the South (St. George's) Channel than passes back, and that consequently there is, irrespective of the tides, a slow current passing from south to north through our district. The fact that so many of our drift bottles have crossed the "head of the tide" from S. to N., and that of those which have gone out of our district nearly all have gone north to the Clyde Sea-area, supports this view, which was regarded by the late Hydrographer, Admiral Sir William Wharton, as being *a priori* probable (see "Fishes and Fisheries of the Irish sea," p. 9).

The following further account of the minor tidal currents in the immediate neighbourhood of the Isle of Man is given as the result of our own observations and information derived from Mr. James Crebbin, Captain of the yacht, and from the Port Erin fishermen (see Chart, fig. 9).

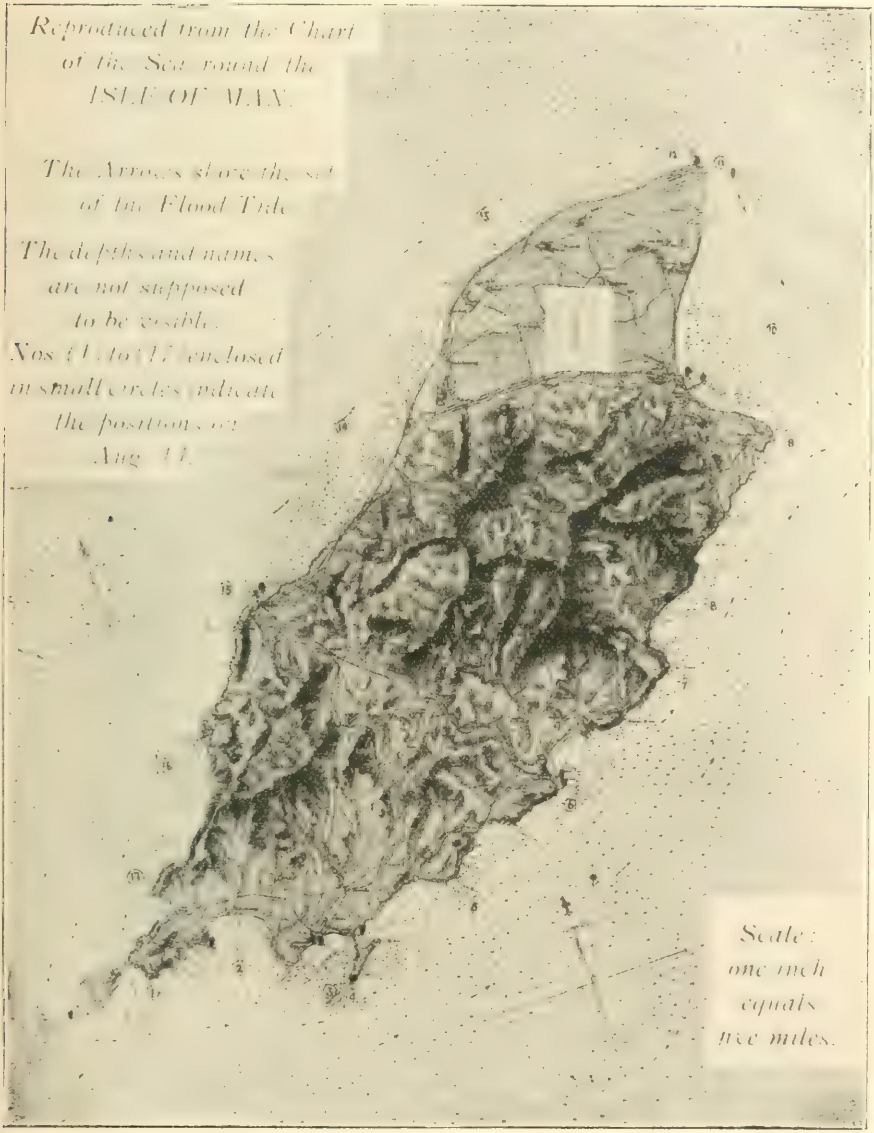

FIG. 9. Set of Flood tide round Isle of Man.

The branch of the southern tidal stream that passes to the west of the Isle of Man meets with the corresponding stream from the north off Contrary Head, near Peel, and the southern stream then turns inshore and flows southwards along the coast over an area extending to from four to five miles from the shore. The current thus runs past Port Erin from the north, towards the Calf Island, as the tide is rising on the shore. This stream begins to flow about an hour and a half before high-water at Liverpool. Outside, say, an average distance of five miles off the land to the west of Port Erin there is very little tidal current. One branch of this south-going flood tide sets from close to Bradda Head towards the Calf Sound, and is known as the "Bowlane tide." Outside that for a couple of miles there is less stream, and then a larger branch forms the main tide which runs from about three miles west of Contrary Head to about one mile west of the Calf Island, where it meets a part of the tide flowing up Channel from the south, and together they turn to the east, rush past the Chicken Rock, and make along the south coast of the Island for Langness Point, round which the current forms a strong race. The tide continues up the east side of the Island to Maughold Head, and can be felt to a distance of at least eight miles off the shore. At Maughold Head this flood tide running north meets with the tide from the north end of the Island which has just come across Ramsey Bay, and they both turn outwards so as to run side by side to the eastward towards Morecambe Bay in Lancashire.

At several points on the east side of the Island, close in to shore, there is a narrow current running south, while the flood tide further out runs north. This is the case, for example, between Port St. Mary and the Calf Sound, where the main flood tide runs for Langness and an inner eddy sets southwards close to the rocks.

About an hour before low-water on the shore the young flood begins to set to the south through the Calf Sound, while the tidal ebb streams are still running in the neighbourhood in the opposite direction.

The North Channel tidal stream reaches the Isle of Man about Contrary Head, and turns to flow northwards to Point of Ayre as the tide rises. At the north of the Island it joins a branch of the main northern tide running eastwards, and they sweep round the Point of Ayre as a strong race, which sets across Ramsey Bay and the shallow banks outside, and continuing south meets the southern tide off Maughold Head and turns with it to run outwards towards the Lancashire coast at Morecambe Bay.

When the tide turns all these currents are reversed, and the ebb runs to the north from Maughold Head, round Point of Ayre, and down the west coast to Contrary Head, where it meets the ebb tide which sets southwards from Maughold Head, round Langness, through the Calf Sound, and northwards up the west coast past Port Erin and Niarbyl.

It is seen from the above description that the flood tide runs past Port Erin from Contrary Head to the Calf Sound, and up the east side of the Island to Maughold Head, where, if the time of high-water is past, the ebb tide will be found setting to the north round Point of Ayre and down the west side to Contrary Head. It is thus possible, by choosing the right time, to carry the tide practically the whole way round the Island when going south-about from Port Erin on a young flood. This is what we did on August 14th when taking the series of surface temperatures recorded in this report at the points numbered (**1**) to (**17**) on the Chart (fig. 9).

All these tidal streams become greatly increased in alternate weeks at the time of the spring tides, and then run as strong currents past the headlands, such as Langness, Point of Ayre, and practically all round the Calf Island. It is probable that these tidal races give rise also to vertical currents in the water, which may bring up to the surface plankton from deeper zones. Some of our gatherings taken in these strong currents close to the cliffs of the Calf Island have been exceptionally large, and have contained exceptional organisms, possibly as a result of these complex movements and the mixing of various waters. Our observing stations off Port Erin have been carefully chosen, so as to be under different tidal conditions:—Station I, five miles offshore, is just on the outer edge of the main tide running north and south: Station II, ten miles out, is in the central area marked as having no perceptible tide: Station III, along shore to the north, and Station IV, alongside the Calf Island, are both in the inshore tides, the former in a slacker and the latter in a stronger current: and finally Station V, south of Spanish Head, is in a different tidal current which runs from the Chicken Rock Lighthouse towards Langness.

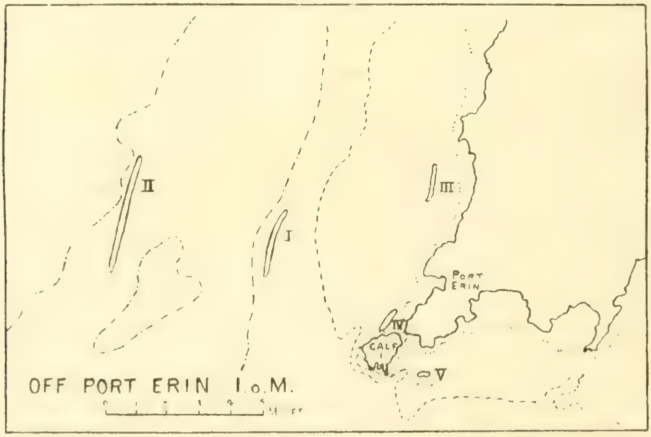

FIG. 10.

The general effect of the flood tides will be to carry more southern, or even oceanic forms, from St. George's Channel into our area. No doubt, on occasions, organisms from the Atlantic water will also be carried in by the northern tide, and may get driven over "the head of the tide" at Contrary Head and at Maughold Head so as to enter our area.

The general effect of the ebb tides will be to bring the less pure coastal waters of lower salinity, with some of their contained organisms, from the shallower eastern parts of the Irish Sea, such as Morecambe Bay, into the purer, salter and deeper water west of the Isle of Man. Most of such coastal water, no doubt, runs clear of the south end of the Calf Island in the ebb tide setting past the Chicken Rock towards St. George's Channel. An inspection of the arrows on the Charts (figs. 8 and 9) will show the trend and influence of these various tidal streams.

The effect of these strong currents, especially at the time of spring tides, upon the influence of the prevalent winds must be very great, and is very difficult to estimate, as the influence is reciprocal, and there are all gradations between high springs and low neaps in the tides and between calms and gales in the winds; and yet all these conditions must play their part in modifying the distribution of the plankton, either by mixing waters and organisms of different source or by driving a planktonic assemblage from or to some area. Swarms may conceivably be sometimes caused and sometimes dispersed by such combined influences of tide and wind.

Finally, we must emphasise once more the marked contrast in physical conditions—and possibly in planktonic contents, although this has not yet been sufficiently demonstrated between the part of the Irish Sea that lies to the east and that to the west of the Isle of Man (see fig. 8). The eastern part is the wide shallow-water area (discussed in the main by Mr. Johnstone and Dr. Bassett in their articles on the temperatures and salinities of the Irish Sea in this report), where the daily rush of the tides mixes up the waters to such an extent that any distinctive characters indicative of origin are obliterated. The water to the west of the Isle of Man, on the other hand, is so much deeper, and that deep water is of such extent, that if the floor of the Irish Sea were raised so as to connect the Isle of Man with Lancashire, there would still be a wide western channel between Port Erin and Ireland not very different in extent from that seen at present. Moreover, this deep-water area west and south of the Isle of Man (see fig. 8) is precisely the region marked on the Admiralty Charts as having no perceptible tidal stream. For these reasons we consider it *a priori* probable that, for example, the water of over 50 fathoms in depth may show stratification in both its physical and its biological characters which will indicate the nature and origin of the layers. Mr. Johnstone tells us that he got no indication of such layers in the deep water at a point further north between the Mull of Galloway and Ireland; but on the other hand, our mid-channel Stations A and B, at 64 and 74 fathoms respectively, and in the comparatively still area referred to, and in the observations we took at these stations last summer, Mr. Drew considers we got evidence of stratification. It is evident that the whole matter requires further investigation: but we must insist in the meantime on the obvious difference in character between the wide, shallow, sandy eastern part of the Irish Sea and the deep channel lying to the west of the Isle of Man. Observations made in the one area, or conclusions drawn from them, must not be regarded as applicable to the whole of the Irish Sea.

DISCUSSION OF THE GROUPS.

We now return to the plankton results, and shall consider first the leading groups captured inside the bay.

BAY DIATOMS IN 1908.

The number of Diatoms per haul in Port Erin Bay starts with 6,200 on January 4th, and rises gradually through an average of 8,995 in January, 19,625 in February, 66,831 in March, to 484,419 in April. There is a sudden increase in the middle of April from 64,750 on April 7th to 329,450 on April 13th, and after that the numbers rapidly rise to 1,775,700 on April 29th, to 2,290,000 on May 20th, and, with falls between, to 2,873,150 on May 28th, and 2,191,250 on May 30th. The numbers keep high during the first week of June, drop in the middle of the month, and rise again to over one and a half millions at the end (with an exceptional haul of over three and a half millions in the coarse net on June 30th); after which there is a rapid fall in the first half of July leading to a still further reduction in August—when Diatoms are practically absent. On September 14th the numbers have risen again to 6,800 in the fine net, and 2,400 in the coarse net; but the average for the month is only 1,413, taking both kinds of net into consideration. The numbers are higher for October, reaching 149,300 in the fine net, on the 16th, but dropping again to 2,700 at the end of the month. On November 2nd they rise to 6,830 and on November 6th to over 7,700, but drop again by the 30th to 1,860, and on December 4th to 1,230, on December 15th to 210, and on the 23rd to 330. The numbers taken in the coarse nets during December are much higher, 14,500 on December 4th, 5,600 on the 15th, 9,030 on the 23rd, and 5,700 on the

30th, making an average of 5,228 per haul for the month, taking both nets into consideration.

When compared with last year's curve, the above record shows that in spring the usual great increase in number of Diatoms was much later in 1908. The numbers are lower in January, February and March, and the sudden rise does not begin until further on in April, although it afterwards, late in April, when Diatoms were almost absent in 1907, attains to a much greater height. But perhaps the most remarkable feature of this year's phyto-plankton is the enormous increase in May, reaching nearly three millions per single 15 minutes' haul across the bay at the end of the month. In fact, with occasional drops, the number is up in the millions for a great part of the two months May and June—a period when the numbers were not at all high in 1907.

From the middle of July onward there is no great difference between the two years. This year, again, in August Diatoms are practically absent, and again there is a second, but lesser, late autumn maximum. This rise is, however, in 1908 not until the third week of October, after which the figures keep low, under 10,000 per haul (with one rise to 14,500), throughout November and December. Both the spring and the autumn maxima were thus much later than in 1907, and the numbers of Diatoms obtained in individual hauls were not nearly so great at either time of year—reaching to not quite 150,000 in autumn this year as against 13,000,000 and 16,000,000 in 1907.

Just as it has been found necessary to analyse the total plankton into its constituent groups, since Diatoms and Copepoda, for example, do not reach their maxima at the same season, so it may in some groups be necessary to analyse the totals still further and consider the distribution of the separate genera or even species throughout the year. The Diatoms and the Copepoda are certainly such groups, as we have in each case abundant evidence that different representatives of the group flourish best at different seasons. Consequently we have now picked out from the Diatom records the detailed occurrence of the five leading genera, *Biddulphia*, *Chaetoceros*, *Coscinodiscus*, *Rhizosolenia* and *Thalassiosira*, with the results given in the following lists:—

BAY DIATOMS, IN 1908, BELONGING TO THE FIVE GENERA.

Date.	Biddulphia.	Chaetoceros.	Coscinodiscus.	Rhizosolenia.	Thalassiosira.
Jan. 4 ...	2,000	1,700	2,150	0	0
,, 7 ...	3,850	1.500	2,100	0	0
,, 14 ..	6,700	225	4.375	0	0
,, 20 ...	7,500	1,050	2,725	0	0
Feb. 4 ...	10,000	750	4.800	0	0
,, 6 ...	15.500	1,625	6,800	0	0
,, 10 ...	1,300	200	2.300	0	0
,, 13 ...	9,000	800	5,600	0	0
,, 17 ...	15,000	1,500	22,250	0	0
Mar. 4 ...	24,500	700	6.800	0	0
,, 11 ...	8,000	150	5.000	75	0
,, 17 ...	50,000	12,000	65,000	0	0
,, 21 ...	52,000	9,200	33,000	0	0
Apr. 2 ...	14,000	6,250	25.000	0	0
,, 7 ...	33,000	10,250	21,500	0	0
,, 13 ...	145,000	48,000	119.700	4,700	2,000
,, 14 ...	115,000	40,100	120,000	6.000	14,000
,, 16 ...	155,000	73,750	34.500	0	0
,, 17 ...	73,500	62,000	19,750	0	500
,, 18 ...	100,000	61,000	88,000	2,000	2,500
,, 18 ...	71,000	51,000	85,000	1,000	1,300
,, 20 ...	45,000	248,000	59,000	0	2,000
,, 21 ...	47,500	129,000	53,000	500	0
,, 21 ...	25,500	128,500	52,000	1,000	500
,, 21 ...	26,000	113,000	51,000	500	0
,, 21 ...	31,000	261,000	46,000	500	250
,, 22 ...	47,000	217,125	54,000	1,250	3,500
,, 22 ...	25,000	354,000	27,000	750	1,000
,, 22 ...	25,000	282,750	47,000	500	1,500
,, 23 ...	45,500	302,750	14,500	250	8,000
,, 23 ...	53,000	730,000	40,000	3,000	2,000
,, 23 ...	46,000	873,500	35,500	2.500	1,000
,, 24 ...	41,000	435,000	26,000	3,500	3,000
,, 24 ...	45,000	608,000	27,500	3,500	4,000
,, 25 ...	78.025	584.625	9,625	5,000	2.000
,, 25 ...	46,000	836,000	5.400	8,000	0
,, 25 ...	44.000	816,000	6.500	7.500	0

Date.	Biddulphia.	Chaetoceros.	Coscinodiscus.	Rhizosolenia.	Thalassiosira.
Apr. 27 ...	81,000	1,245,000	18,000	7,000	15,000
,, 29 ...	95,500	747,750	12,625	7,500	65,000
May 12 ...	1,125	25,000	6,625	750	250
,, 20 ...	0	2,005,000	5,000	150,000	80,000
,, 26 ...	0	187,500	500	122,000	0
,, 28 ...	0	2,348,500	5,000	465,000	500
,, 30 ...	125	935,000	125	680,000	750
June 2 ...	0	817,500	0	705,000	2,500
,, 4 ...	0	367,000	2,500	1,137,500	7,500
,, 6 ...	0	78,500	100	325,000	0
,, 10 ...	0	12,750	500	0	0
,, 12 ...	0	375	500	21,000	0
,, 18 ...	0	135,500	2,500	390,000	0
,, 25 ...	0	47,500	0	1,135,000	0
,, 30 (c.)	0	4,000	500	3,519,000	0
July 2 ...	0	25,000	0	1,032,500	0
,, 7 ...	0	5,500	0	128,000	0
,, 14 ...	0	875	125	11,600	0
,, 21 ...	0	1,975	250	30,125	0
,, 27 ...	0	150	0	375	0
Aug. 5 ...	0	500	0	0	0
,, 5 ...	0	0	0	0	0
,, 7 ...	0	750	0	300	0
,, 7 ...	0	300	0	0	0
,, 18 ...	0	2,800	0	300	0
,, 26 ...	0	1,200	600	900	0
,, 28 ...	0	60	60	30	0
,, 28 ...	0	100	0	150	0
,, 29 ...	0	25	0	0	0
,, 29 ...	0	50	0	20	0
Sept. 14 ...	1,180	3,310	160	80	0
,, 16 ...	900	375	0	0	0
,, 17 ...	12	350	25	0	0
,, 21 ...	400	400	40	0	0
,, 22 ...	825	1,505	40	50	0
,, 24 ...	405	520	25	0	0
,, 25 ...	100	325	0	0	0
,, 28 ...	210	440	0	0	0
,, 29 ...	450	300	25	12	0
,, 30 ...	710	450	82	0	0
Oct. 1 ...	970	875	65	20	0
,, 2 ...	2,125	1,850	25	25	0
,, 3 ...	2,190	3,750	65	25	0
,, 5 ...	3,950	5,400	260	100	0
,, 6 ...	1,850	12,800	125	200	0
,, 7 ...	1,350	9,550	150	200	0
,, 8 ...	1,100	5,300	150	250	0
,, 9 ...	2,750	1,775	125	50	0
,, 12 ...	275	3,275	100	150	0
,, 13 ...	800	18,600	700	1,200	0
,, 14 ...	500	1,150	250	25	0
,, 15 ...	400	25,800	350	1,150	0
,, 16 ...	900	70,050	550	650	0
,, 17 ...	300	14,195	480	175	0
,, 19 ...	592	3,200	80	12	0

Date.	Biddulphia.	Chaetoceros.	Coscinodiscus.	Rhizosolenia.	Thalassiosira.
Oct. 20 ...	525	1,500	62	50	0
,, 23 ...	112	550	50	12	0
,, 24 ...	150	1,172	62	25	0
,, 26 ...	325	1,775	237	12	0
,, 28 ...	365	3,855	260	15	0
,, 29 ...	280	2,455	505	50	0
Nov. 2 ...	1,090	3,050	645	15	0
,, 6 ...	1,750	2,405	915	105	0
,, 10 ...	1,620	435	840	65	0
,, 13 ...	3,375	2,762	612	37	0
,, 30 ...	2,185	715	530	0	0
Dec. 4 ...	4,190	2,630	955	15	0
,, 15 ...	1,990	500	415	0	0
,, 23 ...	3,300	425	880	0	0
,, 30 (c.)	5,000	200	500	0	0

In comparing curves drawn from these lists, it is found that the curve for the total Diatoms in the bay from January to April practically agrees with the curves of *Biddulphia* and *Coscinodiscus*, and these two agree with one another. From April 20th onwards the maxima are caused in turn by *Chaetoceros debile* on April 29th, by *C. sociale* in May, by *C. sociale* and *C. teres* and *Rhizosolenia* in early June, and by *Rhizosolenia* and *Guinardia flaccida* in late June and early July. The maxima in total plankton catch coincide with the above-noted Diatom maxima, with the exception of that on June 10th, apparently caused by *Evadne* and Copepoda. *Biddulphia* and *Coscinodiscus* influence the value of the total catch apparently far more, in proportion to their actual numbers, than do *Chaetoceros* and *Rhizosolenia*. This is no doubt due to their larger size individually.

It will be noticed that the maximum for *Biddulphia* and for *Coscinodiscus* is about the middle of April, for *Chaetoceros* late in May, and for *Rhizosolenia* at the end of June. The minima also differ, *Biddulphia* being practically absent when *Chaetoceros* and *Rhizosolenia* are present in greatest abundance.

In considering how the chief elevations in the Diatom curve throughout the year are caused, we find that *Biddulphia mobiliensis* is one of the earliest species to appear, and is responsible for the moderate rises in February and March. The earliest of the April forms are *Coscinodiscus radiatus* and *C. concinnus*, which flourish, along with *Biddulphia mobiliensis*, in the middle of April, and are followed by *Chaetoceros debile* at the end of the month. In May the great rise to between two and three millions is caused by *Chaetoceros sociale*, and in the early part of June by that same species along with *Chaetoceros teres*, *C. debile*, *Rhizosolenia semispina* and *Rh. shrubsolei*. The great elevation at the end of June and beginning of July is mainly caused by the same two species of *Rhizosolenia*, along with *Guinardia flaccida*. The rise in the middle of October is due to *Chaetoceros decipiens*, and *Ch. criophilum*; and after that period no species is specially abundant during the remainder of the year.

Chaetoceros contortum and *Thalassiosira nordenskioldii*, which were mainly responsible for the spring maximum in 1907, have been less prominent this year, the former reaching only to 60,000, on April 23rd, and the latter 80,000, on May 20th, as against the millions present per haul in the previous year. But perhaps the greatest contrast between the two years in the prevalence of Diatoms is seen in September, when in 1907 thirteen millions and sixteen millions of one species, *Rhizosolenia semispina*, were taken in two simultaneous hauls of the surface nets at Station III; at a time and locality when in 1908 Diatoms as a whole were few and *Rhizosolenia semispina* was almost absent, the greatest haul being 8,000 at Station III on September 15th.

BAY DINOFLAGELLATA IN 1908.

During the first quarter of 1908, the Dinoflagellates kept between 150 and 750 per haul, with one rise to 1,000 on February 17th. On April 13th there was a sudden rise to 3,100, followed by rapid fluctuations between 0 and 2,500 until May 20th, when there was another sudden rise to 80,000. The numbers then dropped by two steps to 7,250 on May 28th, rose by three steps to 135,000 on June 4th, dropped to 13,250 on June 18th, rose again to 137,500, the highest point reached, on July 2nd, dropped suddenly to 18,000 on July 7th, and 1,125 on July 14th. Then there is an upward trend to a maximum of 52,250 on August 5th, after which the curve shows a general downward trend to 125 and 170 on August 29th. During September the numbers are still small. In ten hauls with coarse nets, only twice were any Dinoflagellata caught—on September 14th and 21st, with 100 and 4,000 respectively. With the fine nets the numbers varied from 0 to nearly 2,000, until September 30th, when we got 3,650. From October 1st to 13th catches from the coarse nets rose irregularly from 0 to 1,000, and fluctuated during the rest of the month from 0 to 500; and from the fine nets they started on October 1st at 1,600, rose on the 2nd to 1,900, then dropped through 850 and 800 to 0 on the 6th, rose again to 5,400 on the 13th, and kept ranging from 0 to 3,100 during the rest of the month. On November 2nd, 6th and 10th, three hauls with coarse nets caught none, but the number rose on the 13th to 75, and on the 30th to 240: while with the fine nets the numbers range from 60 to 1,100 on the 13th. In December the numbers continued to keep low, the highest being 510 on December 4th in the fine net, and dropping to 240 on the 23rd, while the numbers with the coarse nets ranged from none to 100.

If we compare the above record with that for 1907 we find that during the first four months in the present year numbers are generally lower, with a maximum at about 3,000 only, as against 8,000 on April 19th, 1907. On the other hand, from the middle of May to the middle of July, the period in which the highest catches (up to 137,500 on July 2nd) were made in 1908, the numbers in 1907 ranged from 375 to 3,375 only. In August and September again the catches were rather higher in 1907

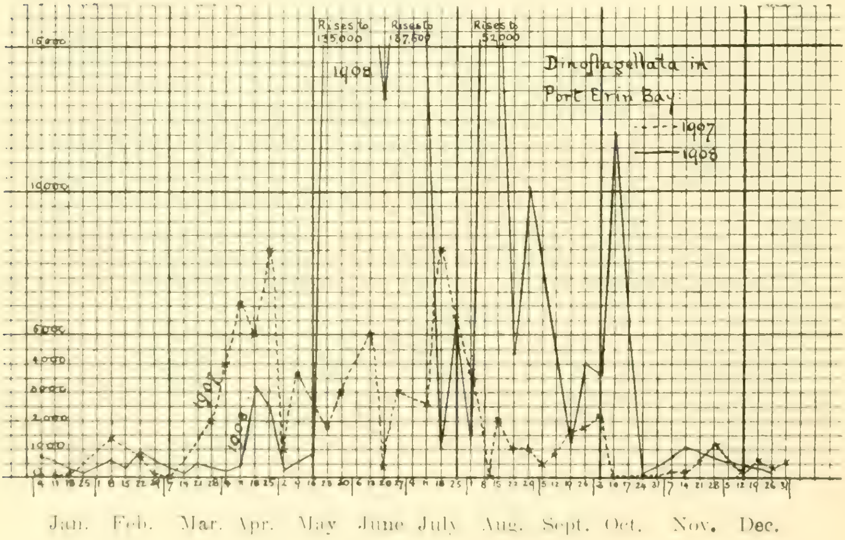

FIG. 11.

than in 1908. No Dinoflagellates were caught (four hauls only) in October, 1907, while in 1908 (many more hauls) they ranged up to 3,100. The numbers for November and December were slightly lower this year than last. The above comparison and an inspection of the superimposed curves for the two years (fig. 11) shows at once that the chief differences are due mainly to the maxima being later in 1908, the great early summer elevation being in May to July in place of April, and the autumn increase in October being about a month later than in 1907. The various elevations are also seen to be much higher in 1908.

Bay Copepoda in 1908.

The Copepoda in 1908 show at least three distinct maxima, at the end of March, the middle of June, and in September and October. An unusually large haul for a winter gathering (1,170 mainly composed of *Pseudocalanus elongatus*, *Acartia clausi*, and *Oithona similis*) was obtained on January 7th, and from this there was a gradual but fluctuating decrease to 152 on March 11th, then a sudden rise to 3,830 on March 17th, after which the numbers keep up till April 2nd, followed by a sudden fall to 420 on April 7th. The value fluctuates from 0 to 500 till April 18th, when it rises to 1,280. Further rapid fluctuations lead to an elevation of 2,520 on April 25th. There is then a fall to 18 on May 12th. From this point the value rises quickly, though gradually, to 3,792 on June 4th, drops to 325 on June 6th, rises again to 4,314 on June 10th, drops to 150 on June 25th, after which the value keeps fairly low (with the exception of a rise to 2,035 on August 7th) until the end of August.

On June 30th an exceptional 15 minutes' haul was taken with a coarse net (No. 6 silk) which gave 22 c.c. of total catch, including 8,650 Copepoda, as against 150 Copepoda on June 25th and 332 on July 2nd with the ordinary fine nets.

Beginning with September, both coarse and fine nets were used in the bay as well as outside, as follows:—

Coarse Nets.—On September 14th the number is 64,470 — this drops steadily by three steps to 2,870 on September 21st, rises again to 11,740 on September 28th, and drops to 4,609 on September 30th. It fluctuates in the first week in

October between 2,650 and 9,000; then on October 8th is a sudden rise to 33,970, a drop on October 9th to 12,120, and a rise on October 12th to 39,000; 13th 19,540; 14th 35,200; 15th 16,480; 16th 16,500; and then fluctuates between this and 11,958 until October 29th, when there is another rise to 23,780. November 2nd shows a drop to 19,065, and for the rest of the month the number fluctuates from 2,794 to 5,340. Finally the curve rises steadily from 3,925 on December 4th to 7,650 on December 30th.

Fine Nets.—Starting on September 14th at 3,545 the number drops suddenly on the 16th to 567 and on the 17th to 207; on the 21st rises to 4,640; then drops steadily to 231 on the 29th, but rises to 913 on the 30th; drops to 727 on October 1st, rises on the 2nd to 1,029; on the 3rd and 5th the numbers are 903 and 901 respectively. There is a sudden rise on October 6th to 12,560, a drop by three steps to 344 on October 9th, a rise by two steps to 1,895 on October 13th; drops again to less than 600 on October 14th and 15th; a sudden rise to 2,880 on October 16th; drops to 468 on October 17th; 285 on the 19th; 457 on 20th; 255 on 23rd; 941 on 24th; and 525 on 26th. Then rises to 1,077 on 28th—then drops steadily to 160 on November 10th this is doubled on the 13th, but drops again to 94 on December 4th and rises through 121 to 261 on December 23rd.

The first Copepod maximum is due to a sudden increase of the two species *Pseudocalanus elongatus* and *Oithona similis.* Without these species the numbers for March 17th and 21st and April 2nd respectively are only 130, 26, and 140. The maximum in June is mainly composed of *Oithona similis* and *Temora longicornis*, in September of *Pseudocalanus* and *Oithona*, and in October of the same two forms with the addition of *Acartia clausi.*

On comparing with the Copepod record for 1907, we find that the numbers are not nearly so high for the first half of the present year. In 1907 the Copepoda rose to nearly 30,000 on April 27th and 15,000 in June, as compared with about 4,000 this year. Then again on October 14th, 1907, the record reached 27,000, while this year the only high record in autumn is 12,560 on October 6th.

We have taken out for separate treatment the six more important species of Copepoda (viz., *Calanus helgolandicus*, *Pseudocalanus elongatus*, *Acartia clausi*, *Oithona similis*, *Temora longicornis*, and *Paracalanus parvus*) with the results shown in the following list:—

BAY COPEPODA, IN 1908, BELONGING TO THE SIX GENERA.

Date.		Calanus.	Pseudo-calanus.	Acartia.	Oithona.	Temora.	Paraca-lanus.
Jan.	4	6	250	160	450	0	300
,,	7	15	450	312	288	0	83
,,	14	1	0	10	200	0	80
,,	20	9	10	100	640	0	150
Feb.	4	4	30	5	300	0	50
,,	6	17	175	10	400	2	100
,,	10	6	150	0	15	1	15
,,	13	0	60	40	10	0	0
,,	17	0	75	30	55	0	10
Mar.	4	2	150	10	215	0	5
,,	11	0	2	0	150	0	0
,,	17	30	2.400	40	1,300	60	0
,,	21	1	2,500	20	600	5	0
Apr.	2	0	1.500	60	2,450	40	0
,,	7	0	250	80	80	10	0
,,	13	0	0	0	0	0	0
,,	14	0	300	80	10	20	0
,,	16	0	65	90	5	5	0
,,	17 (c.)	0	1,500	825	75	60	0
,,	17	0	310	50	0	10	0
,,	18	0	1.000	200	40	40	0
,,	18	0	500	20	20	40	0
,,	20	0	180	15	0	3	0
,,	21	0	825	30	15	300	0
,,	21	0	600	15	15	450	0
,,	21	1	840	30	15	150	0
,,	21	0	780	30	15	180	0
,,	22 (c.)	0	680	20	0	100	0
,,	22	0	125	10	0	15	0
,,	22	0	65	10	3	50	0
,,	22	0	100	5	5	75	0

Date.	Calanus.	Pseudo-calanus.	Acartia.	Oithona.	Temora.	Paraca-lanus.
Apr. 23 (c.)	0	12	30	0	40	0
,, 23	0	19	1	0	1	0
,, 23	0	550	30	0	30	0
,, 23	1	275	5	0	5	0
,, 24	0	140	10	0	15	0
,, 24	0	150	20	0	30	0
,, 25 (c.)	0	900	100	0	200	0
,, 25	0	100	20	0	50	0
,, 25	0	2,250	10	50	210	0
,, 25	0	500	10	50	210	0
,, 27	0	260	150	30	180	0
,, 29 (c.)	8	2,000	150	0	165	0
,, 29	0	650	40	0	60	0
May 12	0	13	1	2	2	0
,, 20	0	35	25	5	60	0
,, 26	3	100	80	0	265	0
,, 28	0	170	110	10	225	0
,, 30	5	75	200	325	205	0
June 2	15	175	125	600	365	0
,, 4	15	113	225	3,200	188	0
,, 6	0	0	10	320	5	0
,, 10	210	60	260	1,700	2,000	20
,, 12	183	250	105	400	1,900	0
,, 18	27	150	330	2,590	230	0
,, 25	1	5	18	68	50	0
July 2	50	38	43	158	30	0
,, 7	8	5	8	50	8	0
,, 14	13	8	90	5	15	0
,, 21	18	20	10	20	75	3
,, 27	15	0	113	38	30	0
Aug. 5	5	60	50	470	100	5
,, 5	30	170	110	1,000	160	0
,, 7	1	20	40	850	60	5
,, 7	5	60	40	1,750	170	0
,, 18	3	122	25	375	15	0
,, 26	65	125	15	745	215	65
,, 28	2	2	0	33	12	1
,, 28	20	10	0	100	40	0
,, 29	8	15	0	55	20	3
,, 29	12	14	0	160	12	2
Sept. 14 (c.)	1,370	10,000	600	40,000	3,000	9,000
,, 14	15	200	100	2,000	70	150
,, 16 (c.)	2,000	18,000	1,500	17,000	300	7,500
,, 16	22	220	25	250	15	20
,, 17 (c)	550	3,750	350	10,000	300	1,750
,, 17	7	85	20	70	5	15
,, 21 (c.)	30	910	270	1,135	80	430
,, 21	5	1,400	100	2,720	100	260
,, 22 (c.)	2	1,250	3,500	2,200	300	640
,, 22	0	100	120	750	3	50
,, 24 (c.)	46	3,000	1,900	1,150	260	800
,, 24	5	180	300	600	20	30
,, 25 (c.)	25	5,000	1,000	1,650	300	1,100
,, 25	30	55	450	180	30	80
,, 28 (c.)	60	3,750	1,830	3,700	140	2,000
,, 28	1	160	80	250	40	75
,, 29 (c.)	23	2,750	2,630	3,460	150	900
,, 29	0	65	70	75	1	15
,, 30 (c.)	1	400	640	2,240	15	1,280
,, 30	3	100	40	565	10	175

Date.	Calanus.	Pseudo-calanus.	Acartia.	Oithona.	Temora.	Paraca-lanus.
Oct. 1 (c.)	1	900	520	2,600	40	1,800
,, 1	0	235	30	300	4	155
,, 2 (c.)	5	2.750	1,450	1,650	50	1,650
,, 2	2	280	470	190	2	80
,, 3 (c.)	0	1.500	380	1.620	100	530
,, 3	1	300	250	200	10	150
,, 5 (c.)	0	600	760	2,000	0	400
,, 5	0	120	220	520	3	35
,, 6 (c.)	0	190	1.350	840	15	175
,, 6	0	1,200	8,000	1,700	120	1,300
,, 7 (c.)	40	3.600	1.000	920	120	3,000
,, 7	25	1,100	1.200	500	20	480
,, 8 (c.)	900	9.200	11.000	2.750	60	10.000
,, 8	300	300	1,000	600	20	300
,, 9 (c.)	400	2,800	2.600	0	80	6,000
,, 9	4	75	75	125	5	55
,, 12 (c.)	4,500	7,000	9,500	10,000	200	7,500
,, 12	100	80	45	415	1	40
,, 13 (c.)	480	1.800	3.500	10.000	30	3.700
,, 13	50	100	275	1.170	0	300
,, 14 (c.)	600	11.250	2.600	16.500	0	4,250
,, 14	15	125	40	275	1	100
,, 15 (c.)	80	8,200	2.000	3.200	0	3,000
,, 15	10	200	90	150	1	75
,, 16 (c.)	0	2,500	4.500	6.500	0	3,000
,, 16	0	150	180	2.500	0	50
,, 17 (c.)	40	1,100	450	12,200	0	1,650
,, 17	1	20	65	350	0	30
,, 19 (c.)	0	400	7.500	6,350	5	430
,, 19	0	20	30	225	0	10
,, 20 (c.)	50	800	1,750	8,750	3	600
,, 20	1	25	75	325	0	30
,, 23 (c.)	1,000	4,500	2.200	6.100	120	1,000
,, 23	40	55	70	80	0	10
,, 24 (c.)	120	2,800	1.600	8,800	40	800
,, 24	65	350	175	320	5	25
,, 26 (c.)	200	4,700	3,000	7.700	25	700
,, 26	30	100	30	350	0	15
,, 28 (c.)	400	2,500	1,800	9,000	80	1.200
,, 28	90	160	80	725	2	20
,, 29 (c.)	1,400	5,500	6.600	7,800	40	2,400
,, 29	165	100	230	350	0	60
Nov. 2 (c.)	40	5,500	7.800	4.000	10	1,700
,, 2	0	250	440	155	2	50
,, 6 (c.)	10	750	700	870	20	1,400
,, 6	0	40	65	120	0	80
,, 10 (c.)	40	1,250	950	2,000	0	1,100
,, 10	2	40	15	90	0	13
,, 13 (c.)	4	600	100	1,500	20	550
,, 13	1	35	65	160	5	35
,, 30 (c.)	26	1,000	140	2,800	0	320
,, 30	1	15	15	180	0	10
Dec. 4 (c.)	45	1,200	160	1,800	0	720
,, 4	6	17	1	70	0	0
,, 15 (c.)	43	900	125	4,300	0	275
,, 15	3	28	5	50	0	35
,, 23 (c.)	2,850	70	300	2,000	0	500
,, 23	16	160	10	70	0	5
,, 30 (c.)	50	7,000	600	0	0	0

The minor maxima of *Pseudocalanus* and *Oithona* in March and April and of *Oithona* and *Temora* in June will be noticed; but the much greater maxima of all species about the middle of September and again in the second week of October is the most conspicuous feature of the list. On the whole, Copepoda were most abundant within the bay this year in the third week of September (over 64,000 in one haul on September 14th, and over 45,000 on September 16th). The distribution of some of the more important Copepoda throughout the year will be considered further on.

IN THE OPEN SEA.

The plankton samples from the open sea to the south and west of the Isle of Man were taken from the S.Y. "Ladybird" during the two critical periods of the year (April) and late summer (August and September), when certain constituents in the plankton attain their maxima of development; and these may now be considered in relation to the other observations discussed above which were taken throughout the year from smaller boats in the inshore waters of Port Erin Bay.

During the spring, part of a month (April 11th to April 29th) was devoted to this work at sea from the "Ladybird," and in the 13 working days during that period we took in all 184 samples, an average of over 14 per day. For example, on April 29th, 20 hauls were taken at Stats. I, II and III with Hensen, Nansen, surface (fine and coarse), weighted and shear nets a collection which enables comparison to be made between these localities with the different nets and within a few hours of the same time.

In the summer and autumn (August 4th to September 19th) the "Ladybird" was again engaged on this work, and during this period 266 gatherings were taken in the 27 working days, an average of nearly 10 per day. On one expedition (August 17th) 25 gatherings were taken; 21 of them being in a small area of only about three miles extent, as follows:—

Stat. A. Nansen net, 60-0, 60-0, 50-0, 20-0.
Hensen net, 60-50, 50-40, 40-30, 30-20, 20-10, 10-0.
Two surface nets, and one weighted net.

Stat. B.—Nansen net, 70-0, 40-0, 20-0.
Hensen net, 70-60, 60-30, 30-20, 20-10, 10-0.

These Stations A and B, which were only visited on occasions, are out in mid-channel, 13 to 14 miles N.W. from Bradda Head, in depths of 64-74 fathoms, and about half-way to Ireland. Station II, which was worked more frequently, is 10 miles off land, and well outside the 20 fathom line, so all of these localities may be regarded as being in that central area of the Western Channel which is little affected by tidal currents. Station I, five miles from Bradda Head, shows more tidal influence than Station II, but less than localities further inshore. Station III, alongshore, to the north of Bradda Head, is in comparatively quiet coastal water, and may serve to compare with Station I, further out to sea, and on the other hand with Port Erin Bay. Stations IV and V are in strong currents close to the Calf Island, but are on opposite sides of the Island and exposed to entirely distinct influences, Station V being in the tide that sets up the east side of the Isle of Man; while Station IV is in the tidal system of the west side. When we consider the tidal and temperature variations in these strong currents close to land, it is not surprising that the plankton catches show great irregularities at these inshore Stations.

Stations I, II and III (map, fig. 10, p. 278) thus seem to be the most instructive for purposes of comparison, and so we have prepared the following table showing the

Date, etc.				Catch.		Diatoms.		Dinoflagellates.		Copepoda.	
				W'ght.	Surf.	Weight.	Surface.	Weight.	Surface.	Weight.	Surface.
April	13.	Sta.	I	4·5	3·85	59.250	78.600	375	1.125	9.575	9.360
,,	13	,,	III	2·7	1·75	195.500	205.350	500	875	6.310	5.338
..	14	..	I	3·5	2·4	197.200	65,975	7.250	5.400	11.072	4.993
..	14	..	III	3·5	2·75	177.000	212,975	---	1,125	5.600	3.845
..	16	..	I	3·5	1·65	78.500	109,000	1.500	1.625	712	2.765
,,	16	,,	II	2·0	1·9	53.000	70,000	1.250	2.500	8.360	5.284
..	16	..	III	4·25	2·25	150,250	104,250	300	125	3.295	12,148
..	17	..	I	1·0	1·0	34,775	18.588	–	838	1.831	1,117
..	17	..	II	1·0	1·0	14,900	27,200	700	788	2.661	1.700
..	17	..	III	1·5	1·0	45,300	44,875	250	1,000	1,055	44
..	22	..	I	1·5	1·2	41,100	91,350	750	1.375	7,870	407
..	22	..	II	6·0	2·25	234,500	224,750	6,500	4,650	21.821	5.210
..	27	..	I	7·5	3·75	822,850	466,125	6,000	1,500	5.242	4.300
..	27	..	II	1·0	1·25	32,875	68,735	225	400	1,067	2,860
..	27	..	III	10.5	5·0	867,675	541,100	—	1,025	1,990	3.210
,,	29	,,	I	8·5	6·0	293,500	326,600	850	7.400	18.940	7.962
,,	29	,,	II	1·0	1·0	24.775	29.025	500	475	1.306	1.628
,,	29	,,	III	10·0	11·0	1,284,000	994.700	500	75	11.670	9.420
Aug.	4.	Sta.	I	1·5	0·65	300	100	15,600	6,650	14,315	4,575
..	4	..	III	1·5	0·8	—	50	15.500	18,050	13,730	18.293
..	6	..	I	0·5	0·5	100	100	3,300	2.350	2,032	1.371
..	6	..	III	0·8	1·65	100	1,125	5.400	39,750	5.287	34.664
..	7	,,	I	0·7	0·8	100	400	8,100	20.800	5,605	122,353
..	8	..	II	0·6	0·4	100	1.100	9,200	10.100	10.862	9,185
..	12	..	I	2·0	0·6	—	—	15,600	2,750	44.060	5,025
..	12	..	III	2·0	1·3	1,250	1,300	27,500	22.900	19.384	13.834
Aug.	13.	Sta.	I	0·9	0·6	200	200	4,000	5,100	7,856	6,836
..	13	..	III	0·6	0·1	—	-	1,700	1,250	1,090	1,192
..	17	..	I	2·5	0·45	2,750	325	7,750	6.150	27,140	4.284
..	17	..	II	1·0	0·25	150	70	7,200	2,725	8.411	1,096
..	18	..	I	1·0	0·9	1,700	650	3,300	2,750	10.477	4.719
..	18	..	III	1·8	0·35	5,000	100	7,900	1,950	20.966	1,443
..	20	..	I	0·6	0·6	500	175	4,100	1,725	11,486	3,987
..	20	..	III	1·0	0·3	3,400	825	7,700	5,400	13,180	2,510
..	22	..	I	1·0	0·2	300	50	2,200	300	7,404	1,485
..	22	..	III	0·3	0·5	600	800	5,500	14,200	6,165	32,600
Sept.	11.	Sta.	I	0·3	0·3	900	1,620	250	510	2,308	3,286
..	11	..	III	1·5	0·4	4,650	3,600	2,900	1,050	16,550	4,890
..	12	..	I	0·8	0·4	550	1,300	200	400	2.365	3,233
..	12	..	II	0·7	0·2	50	—	—	25	802	580
..	15	..	I	0·5	0·2	900	270	150	90	4.038	579
..	15	..	III	1·0	0·7	18,800	6.300	1.360	1,200	88.934	5,498
Averages for April			I	1·28	2·84	218,454	165,177	2.389	2,752	7.892	4,415
			II	2·2	1·48	72,010	83,942	1,835	1,763	7,043	3,336
			III	5·4	3·96	453,288	350,542	259	704	4,987	5,667
Averages for Aug. and Sept.			I	1·03	0·5	692	433	5,379	4,131	11,590	13,478
			II	0·77	0·28	100	390	5,467	4,283	6,692	3,620
			III	1·17	0·68	3,756	1,567	8.384	11,750	20.587	12,658

catches of Diatoms, Dinoflagellates and Copepoda at each of these three Stations with the surface and the weight (10-0 fathoms) nets on all occasions (except April 11th, accidentally omitted, but not differing from the rest) when hauls were taken on the same, or an adjoining, day.

On the whole, larger catches were obtained at Station III than at Station I, and at Station I than at Station II—both in spring and in summer as the lines of averages at the foot of the table show. In April the preponderating influence is due to the presence of Diatoms, and in August to the Dinoflagellata and Copepoda. For a marked contrast in the nature of the catches see April 29th, with over a million of Diatoms in the weight net, and August 4th, immediately below, with none. It will be noticed that Station III which is so rich in Diatoms, in April, is the poorest in Dinoflagellata; while in summer it is the richest in that group and also in Copepoda.

Although there is no high Copepod maximum in the spring of 1908, such as occurred in April 1907, and although throughout most of the year no great swarms of species appeared like some of those in the previous year, still there are some hauls that showed a fair number of species represented by moderate figures, and we quote Form **77** as an example. The first two columns are hauls in Port Erin Bay on September 14th, and all the rest are seven hauls at Station I. on September 15th. The only really large number is the 40,000 of *Oithona similis* in the coarse net on September 14th.

77.—Bay (1 & 2) September 14; and Station I., September 15.

Net used.	1. Coarse.	2. Fine.	Coarse.	**Fine.**	Hensen 20-0 (open).	Hensen 20-10	Nansen 20-0 (open).	Nansen 20-10	Weight.
Calanus helgolandicus	1.370	15	260	2	20	3	14	2	26
Pseudocalanus elongatus ...	10,000	200	1.350	6	530	75	600	300	275
Temora longicornis	3.000	70	50	1	20	12	10	5	12
Centropages hamatus	350	10	300	1	20	12	10	5	30
Anomalocera pattersoni ...	—	—	4		—	—	—	—	—
Acartia clausi..................	600	100	700	4	160	120	40	80	480
Oithona similis	40,000	2,000	10.000	50	670	225	520	110	100
Paracalanus parva	9.000	150	1,400	2	-	80	40	20	45
Isias clavipes	150	—	520	3	40	12	20	5	720
Diaixis hibernica	—	—	—	-	—	—	10	—	—

Form **51**, part of which is quoted here, shows a similar case for the Dinoflagellata several species being well represented in every haul. This series includes a very high number, 400,000, of *Ceratium tripos* obtained in the new surface net - a far greater quantity than anything obtained last year; even the 16,300 and the 19,500 and 20,000 are exceptionally high numbers.

51. —Station III., August 12 (**2 miles to the S.W.)

Net used.	Surface.	"New."	"Pulley"	Hensen.	Nansen.	Weight.	*"New."	*Surface.
Ceratium furca	1,700	2.000	450	825	1.200	3,000	300	250
" fusus	4.600	2.000	1.725	2.700	1,900	3,500	400	1,000
" tripos.........	16.300	400,000	7.500	3.900	3,500	19,500	20,000	3,500
Peridinium sp.	300	5.500	300	225	100	1,500	700	200

We shall now take out some of the chief species of Copepoda, Cladocera, worms, &c., and briefly summarise their occurrence during the year for comparison with 1907.

COMMON COPEPODA IN 1908.

Pseudocalanus elongatus is very generally distributed throughout the year, and also throughout the nets at those times of the year when different nets were used. The numbers are occasionally high; for example, in the latter half of March we find 2,400 and 2,500 specimens in the surface net in the bay on two occasions, and early in April we find 2,750 in the "weight" net at Station III, and 1,000 on several occasions during that month in the same net. The highest number in the bay during April is 2,250. The numbers run lower during May, June and July, but in August we again find hauls of 1,000 and 2,000 on occasions in the "weight" net. In the middle of September there is an increase, and the coarse surface net took 10,000 in the bay on the 14th and 18,000 in the bay on the 16th. The numbers keep high in that net to the end of the year, being over 9,000 on October 8th, over 11,000 on October 14th, and 7,000 on December 30th. In the fine net during the same period the catches are generally a few hundreds, sometimes less—1,000 is reached on two occasions. The shear net and Yngel trawl in August and September sometimes obtained very large numbers of this and other Copepoda, such as 433,000, mainly *Pseudocalanus*, on August 8th.

Calanus helgolandicus occurs throughout the year, but the numbers are low in the first quarter, and are still lower in April, when the greatest haul is 60, and many have only single specimens or none at all. The first high numbers occur in June (210 on the 10th and 183 on the 12th) in the surface net within the bay. It is not again until August that the hundreds are reached (500 in the "pulley" net and 800 in the "new" net on August 6th). The numbers run still higher in September and October, and on occasions up to the end of the year—for example, September 14th, 1,370; 16th, 2,000; October 12th, 4,500; 23rd, 1,000; 29th, 1,400; December 23rd, 2,850. All these high numbers were taken with the coarse net, this being one of the larger, more powerful, swimming animals which in all probability escape from the feebler current at the mouth of the fine net. The shear net and Yngel trawl during August and September also frequently took very large numbers of *Calanus*, such as 22,500 on August 8th.

Anomalocera pattersoni only occurs between the middle of April and the middle of September, and, in fact, is only present in numbers above 20 during the latter half of April. During that period nearly all the catches were outside the bay at Stations I and II. Compared with last year, the numbers are, as a rule, not nearly so high—the maximum this year being only 160 in the coarse net on April 29th at Station II, as compared with 560 in a fine net on April 16th, 1907, at Station V. The biggest number caught in a fine net in 1908 was 90 on April 29th at Station I. Last year it was first caught (in metanauplius stage) on March 29th—a full fortnight earlier than this year. Between August 6th and September 15th, 1908, it was only represented by a very few specimens in six gatherings, while in 1907 it was represented up to November 8th.

Temora longicornis again shows a fairly even distribution, being represented by small numbers (such as 10 and 20) in nearly every net in most months of the year (only absent in January and December). This species is occasionally found in denser swarms, which accounts for the quite sudden larger catches that were sometimes obtained, such as 300 and 450 in the bay on April 21st, while the number on the preceding day was three only, and on the following day 15. In the end of May and early part of June there seems, however, to be a steady increase, from 60 on May 20th, through numbers between 200 and 360, up to 2,000 on June 10th and 12th; after which the numbers fall again to 230 on the 18th and 50 on the 25th. The coarse net in September obtained some large catches, such as 450 at Station III on September 11th, 3,000 in the bay on September 14th, and 2,550 at Station III on September 19th. Towards the end of September the numbers range from 100 to 300.

Centropages hamatus is again present throughout the year, with the exception of January and December. The numbers are low, ranging from one to 60 only in most of the surface nets, both in the bay and open sea, throughout the year. There is no marked maximum at any point, and the only larger numbers are on exceptional occasions, when the "pulley" net, for example, obtained 200 at Station I on August 19th, and the coarse net in September obtained hauls of 200, 300, 600, up to a maximum of 700 and 750 on several occasions.

MICROCALANUS IN 1908.

The small Copepod *Microcalanus pusillus* appears for the first time this year, in the bay surface nets, on February 4th; and on February 6th and April 2nd it occurs again. Throughout April it is practically restricted to the Hensen and Nansen nets open only between 20 and 10 fathoms, with the exception of hauls on April 24th and at Station III on April 29th, when the nets were open to the surface. After April 29th for nearly two months no specimens were found. It must be remembered that during May and June the yacht was not at sea, and the only collections taken were those across the bay. It is *possible* therefore that *Microcalanus* may have been present outside the bay during this period when it was apparently absent in the bay. On June 25th and August 5th the species occurs again in the bay nets. From August 5th to September 14th it occurs only in the Hensen, Nansen and weight nets (some of which, on August 17th and on September 12th, were hauled from greater depths down to 60 fathoms), with the exception of a large catch of 300 specimens in the coarser surface net at Station I, on September 11th. The frequent occurrence of this form in the Hensen and Nansen nets hauled from 20 to 10 fathoms, and in the weight net in the latter part of the year, the almost entire absence from the surface nets, and the comparatively small number taken in the Hensen net on August 17th—which was hauled from 60 to 50 fathoms—seem to indicate that this species is with us a midwater form. The fact of its being present at the surface in the bay may not mean anything more than that the bay water is a mixture of various layers, caused by the tidal currents in shallow water or by an off-shore wind which has carried the surface water out and allowed deeper layers to well up from below.

The following table shows the distribution in the nets in detail; and although the record for the year differs considerably from that of 1907, still it is not incompatible with the view expressed in last year's report that this may be a species which periodically invades our area. The numbers present in the earlier months of 1908 may well be remains of the previous autumn's invasion. It will be noticed that in April they were mainly caught in the Hensen and Nansen nets hauled from 20 to 10 fathoms, out at sea.

Date.		Station.	Hensen.	Nansen.	Weight.	Surface.
Feb 4	...	Bay	—	—	—	5
,, 6	...	Bay	—	—	—	15
Apr. 2	...	Bay	—	—	—	40
,, 16	...	I	3	4	—	—
,, 16	...	II	2	3	—	
,, 17	...	I	—	25	—	—
,, 22	...	I	4	2	—	—
,, 24	...	I	50, 25	9, 6	—	—
,, 25	...	I	100	110	5	—
,, 27	...	I	150	250	—	—
,, 27	...	II		90	—	—
,, 29	...	I	60	—	—	—
,, 29	...	II	—	5	—	—
,, 29	...	III	—	25, 1	—	—
June 25	...	Bay	—	—	—	3
Aug. 5		Bay	—	—	5	—
,, 12	...	I	20	—	—	—
,, 13	...	I	10	—	10	—
,, 17	...	Mid-Ch. A	5	50, 50, 50	—	—
,, 17	...	,, B	32, 60, 3	10	—	—
,, 18	...	I	—	—	10	—
,, 19	...	I	50	5	—	—
,, 19	...	V	—	—	20	—
,, 20	...	I	—	—	5	—
Sept. 11	...	I	—	—	—	300
,, 12	...	I	—	—	10	—
,, 12	...	Mid-Ch. A	15, 30, 2	—	20	—
,, 14	...	IV	—	—	5	—

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* Sars (*Crust. of Norway*, Vol. IV, p. 157) says that on west coast of Norway "it only occurred in depths of more than 150 fathoms; and it thus appears to be a true deep-water form."

If we except the three specimens found in the bay on June 25th—and these may also have been stragglers—there is an interval of fully three months in which no specimens of this species were captured. During this period it may be that the last of the 1907 invasion died out, and that the numbers that begin again in August, and reach the maximum of 300 on September 11th, represent this year's invasion—which, however, is obviously much less abundant than in 1907, when the maximum reached 2,500, on September 12th in an ordinary tow-net attached to the shear net, which may probably be treated as equivalent to the "weight" net ranging down to 10 fathoms.

CLADOCERA IN 1908.

Evadne nordmanni first makes its appearance in the surface net at Station III on April 11th (a single specimen only), in the weight net at Station I on April 13th, and in the surface net in the bay on May 26th. It rises to a maximum of 12,500 on June 10th, and then rapidly falls off, and continues to be represented by very small numbers on occasions only throughout July and August.

Podon intermedium makes its appearance in the bay on May 26th with 300 specimens in the surface haul. The numbers fall off during June, and remain small in the ordinary fine surface nets in July, August and September. The only high numbers are when the new net caught 1,200 at Station III on August 12th, when the Yngel trawl caught 2,400 on August 8th and 5,796 on August 18th at Station III, and when the coarse net caught 1,500 at Station I on September 11th and 1,800 in the bay on September 14th. The last occurrence for the year was on October 24th.

Cirripede Larvae in 1908.

The Nauplius stage of *Balanus* occurs for the first time on February 13th and again on March 11th. From this time onwards the Nauplii occur in increasing numbers in every catch until their maximum of 30,000 is reached on April 18th. From this date the numbers keep between 800 and 5,500 till April 29th. But three catches of the coarse net show higher numbers, the highest being 9,000 on April 22nd. The numbers taken on April 29th were 75 in the fine net and 6,500 in the coarse. None were taken after that date. The above statement refers to Port Erin Bay. In the open sea, on the whole, fewer Nauplii were taken, and the maximum appears to be a little later. On April 29th, quite large catches were made in the open sea (15,000 in weight net at Stat. III), so that this date cannot safely be taken as the time of their actual disappearance. The "Cypris" stage of *Balanus* appears for the first time in the bay on April 17th (10 in fine net, 15 in coarse), and one or two are taken occasionally from that time onwards up to the disappearance of the Nauplii The Cypris forms are then taken in slightly larger quantities (6, 20, 10, 9, 6, 5) until May 28th, which is the last date on which any Cirripede larvae were taken. In the open sea very much the same results are found, the largest takes being on April 16th (20 in fine net) and on April 29th (42 in coarse net and 16 in fine). This is probably not the real maximum. It is more reasonable to suppose that the maximum is some time in May, as in the case of the same forms inside the bay.

On comparing these 1908 results with those of 1907, we see that this year the Nauplii appeared in the bay gatherings about a week earlier than in 1907, but the numbers were not high until the middle of April, when the maximum of 30,000 was reached on April 18th, as compared with the maximum of 10,450 on April 15th in 1907. From this time until their disappearance at the end of April, the numbers were higher for 1908 than for 1907. On the other hand, the "Cypris" stage was not nearly so well represented in 1908 as in 1907, the maximum being reached on April 29th with 42, as compared with a maximum of over 1,700 on April 15th last year. In both years this form does not appear after the last week in May. On the whole then, here, as in other groups, the present season was a late one; and it looks as if there had been an unusually severe mortality, as although the Nauplii were abundant in the middle of April, very few of the animals were found in the "Cypris" stage later on.

SAGITTA AND TOMOPTERIS IN 1908.

The numbers for *Sagitta* in the bay in the first half of the year keep at a fairly constant but low value (30 or under) until May 28th (70): and then throughout June they fall and then rise to much the same level (25, 43, 33, 48, 65, 69). After some sudden rises and falls in July and August the numbers diminish until on August 28th and 29th *Sagitta* is entirely absent. In the open sea, the maximum is in August, when we have 98 and 150 on August 6th, 120 and 256 on August 7th, 111 on August 12th, 76 on August 13th, 52 on August 19th, and 87 on August 22nd. The numbers rise as a general rule higher than those of the bay, and, as would be expected, the "pulley" net and the "coarse" net catch more than the others.

The biggest catch in the bay was on September 14th, 220 in a coarse net, only 10 in the fine. Throughout

September and October, when *Sagitta* does occur, there are generally more in the coarse net than in the fine; but after September 24th the numbers are low, the highest being 11, until November 6th, when we find 108 (c.), November 10th 84 (c.), then 29, 17, 18, 7, 30, 18 (all coarse nets), the fine nets in each case catching five or under.

Comparing these results with those of 1907, we see that the numbers are lower throughout the present year. The maximum in the bay gatherings (220 on September 14th) is a month later than the much higher maximum (1,800) of 1907; but the maximum in the open sea was in August (256 in coarse surface net on August 7th, at two miles N.W. of Bradda Head). In both years the numbers fell after the maximum, and rose again in the first week of November, to 324 in 1907, and to 108 in 1908.

On the whole, the statement made last year that—"*Sagitta* is present throughout the year; it is most abundant in August, and the minimum occurs in winter (January to March)," still holds, with the qualification that in 1908 the numbers are lower and the maxima are later.

Tomopteris onisciformis occurs, in small numbers only, from February 6th to December 30th. It is probably present in our area throughout the year, and its non-appearance in the records for certain months (January, March, May and July) can probably be explained by the net having failed to capture a species represented by such small numbers. The only larger numbers are apparently exceptional occurrences, such as when the shear net caught 200 at Station I on August 7th and 120 at Station I on September 15th, and when the coarse net caught 65 in the bay on October 7th.

OIKOPLEURA IN 1908.

As in the previous year this widely distributed and constant form occurs in nearly every gathering from Port Erin Bay. It is difficult to see the exact point of the maximum, but fairly high numbers (in the hundreds) are kept up pretty constantly through May, June and July; these numbers, however, are all under 1,000, until September. In the last four months of the year we again see the difference in the catches with the coarse and the fine nets—the catches in the coarse nets being much larger, e.g. 2,400 as against 400 on September 14th, and 7,000 (the maximum) as against 85 on October 28th. After this date the numbers caught in the coarse nets rapidly drop to a few hundreds in November, and to less than a hundred after December 4th; while, in the fine nets, after October 17th the numbers are never higher than 150, and drop to 2 on December 4th and 0 on December 15th and 23rd.

In the open sea, high numbers are much commoner in August and September than in April, the largest catch being 4,400 with the "pulley" net on August 6th, at Station III. In 1907 the highest numbers occurred in April, while this year the maximum was in August for the open sea, and in October for the bay; but it must be remembered that no gatherings were taken outside the bay after September.

FISH EGGS IN 1908.

Fish eggs occurred in the bay in small numbers only until March 11th, when the numbers rose to 59 per haul— of these, however, 50 were Rockling eggs. The totals kept high until April 23rd, the numbers on April 22nd being 40 Rockling eggs and 81 other fish eggs (30 of these were Bib, 20 Whiting, 10 Dab, and 10 Topknot). From

April 24th onwards, until the end of July, fish eggs occurred in diminishing numbers, with a slight rise on May 26th to 20 Rockling eggs and six others. On four occasions only after July were any caught, viz., one on August 7th, and one, two and nine (all Rockling eggs) on September 14th, 17th and 21st respectively.

In the open sea, during April, the numbers were rather higher than in the bay, the biggest catches being on April 11th (at Station I). In one haul there were 65 Rockling eggs, 75 Dab, 60 Cod, 25 each Whiting and Flounder, 20 Dragonet, and 10 Green Cod.

Comparing the bay results with those of 1907, we see that fish eggs were found earlier this year, but the maximum was not nearly so high, being only 121 on April 22nd, as compared with 577 on April 23rd, 1907—these numbers including 40 and 500 Rockling eggs respectively.

We quote here portions of Forms **6** and **7** to show the fish eggs present in four hauls of surface nets and two of weight nets taken on the same day at Station I, five miles from land.

6 and **7.** Fish Eggs at Station I, April 11th, 1908.

	Surface.	Surface.	Surface.	Surface.	Average.	Weight.	Weight.	Average.
Rockling ...	8	40	8	65	30·25	7	20	13·5
Dragonet ...	13	20	0	20	13·25	3	2	2·5
Plaice ...	2	2	0	0	1	0	0	0
Dab ...	15	30	15	75	33·75	6	1	3·5
Flounder ...	25	50	10	25	27·5	0	0	0
Topknot ...	3	3	1	0	1·75	2	1	1·5
Whiting ...	22	15	30	25	23	16	12	14
Cod	80	40	65	60	61·25	12	7	9·5
Green Cod ...	10	15	5	10	10	0	0	0
Long Rough Dab	1	1	0	2	1	0	0	0
Haddock ...	0	0	0	0	0	5	3	4
Totals ...	179	216	134	282	202·75	51	46	48·5

This table shows that out in the open sea, at this date in April, the majority of the fish eggs were close to the surface, and the weighted nets towed at the same time only a few fathoms deeper obtained appreciably fewer (about 25 per cent. only), except in the case of the Haddock. The numbers for the Cod especially show a marked difference between the surface and the deeper layer.

It may be added that this was the first day of the season's work from the Yacht, and all the nets were of new No. 20 silk used for the first time, and so presumably were equally effective in catching power.

For purposes of comparison, we quote now the hauls made on April 17th with fine and coarse nets in Port Erin Bay, and with the weight net at Station III along the coast to the north.

19.—Fish Eggs on April 17th, 1908.

	Stat. III. Weight.	Port Erin Bay. Fine.	Port Erin Bay. Coarse.	Average.
Rockling	7	9	27	18
Dragonet	10	0	1	0·5
Bib	20	2	2	2
Haddock	15	0	4	2
Whiting	40	0	14	7
Dab	10	0	0	0
Plaice	4	0	0	0
Sail Fluke	2	1	3	2
Topknot	10	3	2	2·5
	118	15	53	34

Here the results seem reversed. The weight net has caught most eggs (with the exception of Rockling), and in some cases more than the average number for a surface net on April 11th at Station I. Still, the dates are not the same and the localities are not the same, although not far distant (five miles, and six days, apart) and so we do not press the contrast.

The coarse surface net, with its better draught, as would naturally be expected, caught more than the fine net. The two very much larger wider-meshed nets, the shear net and the Yngel-trawl, also on occasions obtained large numbers of fish eggs; but did not get so many more, relatively to the catch of the coarse net, as we should have expected from their size. We give here a list showing all the hauls of the coarse and the shear nets taken at all the stations and the bay during April, 1908, to illustrate this point. It will be seen, for example, that on April 24th, at Station I, the coarse net took 68 fish eggs and the much

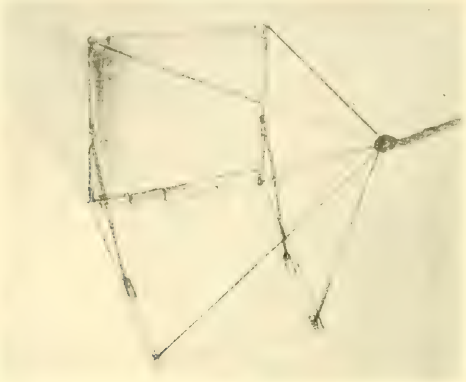

FIG. 12. The mouth of the "shear-net."

FIG. 13. "Yngel-trawl," with "otter boards": *a*, mouth.

larger shear net only 40. The explanation in such cases probably is that the coarse net worked at or near the surface, while the shear net was most of the time in a deeper layer of water (6 to 12 fathoms) where fish eggs were rarer.

Date, &c.	Coarse Net.		Shear Net.	
	Fish eggs.	Notes.	Fish eggs.	Notes.
Apr. 15. Stat. III	—	—	19	(Yngel-trawl)
,, 16 ,, III	6	—	410	Bib, 200 ; Dragonet, 80 ; Rockling, 60 ; Sail Fluke, 30.
,, 17 ,, II	147	Haddock, 86 ; Whiting, 22	—	—
,, 17 ,, III	—	—	1	Haddock.
,, 17 Bay	53	Rockling, 27 ; Whiting, 14	—	—
,, 20 Off Niarbyl	—	—	133	Whiting, 90 ; Rockling, 15.
,, 22 Bay	121	Rockling, 40 ; Bib, 30 ; Whiting, 20	—	—
,, 22 Stat. I	89	Whiting, 20 ; Cod, 18 ; Haddock, 17 ; Rockling, 15	—	—
,, 23 Bay	48	Rockling, 36	—	—
,, 23 Off Niarbyl	—	—	24	Dragonet, 7 ; Topknot, 5.
,, 24 Stat. I	68	Dragonet, 16 ; Bib, 14 ; Rockling, 14	40	Dragonet, 20.
,, 25 Bay	17	Rockling, 9	—	—
,, 27 Stat. I	38	Cod, 9 ; Rockling, 8	—	—
,, 27 Stat. II	63	Cod, 24 ; Rockling, 13	—	—
,, 27 ,, III	17		178	Sprat, 66 ; Dragonet, 47 ; Rockling, 27.
,, 27 ,, III	—	—	69	Dragonet, 23 ; Sprat, 15 ; Lemon Sole, 12.
,, 29 ,, I	114	Lemon Sole, 62 ; Dab, 12	—	—
,, 29 ,, II	96	Green Cod, 68 ; Dab, 10	—	—
,, 29 ,, III	15	—	160	Dragonet, 50 ; Haddock, 20 ; Topknot, 19 ; Rockling, 16.
,, 29 Bay	23	—	—	—
	61 =	Average catch.	115 =	Average catch.

The mouth of the shear net (fig. 12) has about nine times the area of the mouth of the coarse surface net ; and the Yngel-trawl (fig. 13) is still larger.

COMPARISON OF NETS.

One of the objects of this investigation was to compare the performances of the different nets, and try to determine, if possible, which nets could be relied upon to give most nearly representative samples of the plankton.

Coarse and Fine Surface Nets.

The influence of the mesh of the net upon the volume and nature of the catch is well known to all who have had much experience in collecting plankton, and it was remarked upon in last year's report. With the object of getting more definite information on the matter, and also because we were convinced from daily observation that our fine (No. 20) nets were not giving us adequate samples, after occasional trials we started, in September, 1908, using a "coarse" surface net (No. 6 silk) on all occasions along with a fine net of exactly the same size and shape. The results are very interesting. When there is much macro-plankton in the water the coarse net catches much more than the fine, as is shown in the following examples taken at a time of year when Copepoda and other larger Crustacea are abundant on the surface:—

	Sept. 16.	Sept. 17.	Oct. 8.	Oct. 12.	Oct. 14.
Coarse net	19·0	10·0	9·7	14·5	10·5
Fine net	0·6	0·5	1·8	1·0	0·75

But, on the other hand, when the bulk of the plankton is very minute (such as Diatoms and Dinoflagellates), the fine net may catch most, as in the case of the following examples:—

April 23: coarse net 3 c.c.; fine net 17 c.c.
April 29: coarse net 6·5 c.c.; fine net 11 c.c.

Even amongst the Diatoms, however, there are differences, *Biddulphia*, on account of its larger size and shape, being more abundant in the coarse net, and *Chaetoceros* and *Coscinodiscus* in the fine. This is well seen in the following examples of average catches prepared from ten pairs of figures, each pair consisting of fine and coarse net gatherings taken at the surface simultaneously during April.

	Fine Net (No. 20).		Coarse Net (No. 6).
Biddulphia	38,765	...	58,600
Chaetoceros	406,355	...	1,895
Coscinodiscus ...	23,777	...	5,550
Copepoda	156	...	1,007
Fish Eggs	15	...	71
Dinoflagellata	2,787	...	34

The accompanying diagram (fig. 14) shows the graphic relations of these two sets of figures, so as to illustrate the catching power of the two nets for the particular organisms. The columns are of necessity drawn to a different scale for each group, so that the lines for one group are not comparable with those for another—it is only the two catches of the same group that are comparable *inter se*.

The conclusion at which we have arrived is that it is necessary to take both a coarse and a fine net gathering at the same time in order to get anything like an adequate sample of the plankton. It has been shown by several investigators that even the finest meshed silk fails to catch a considerable proportion of the minuter forms of the Protozoa and Protophyta. But it can also be shown that such fine nets do not succeed in bringing up a due proportion of the larger and more powerful swimming organisms, such as Crustacea—probably because of the feebler draught through that type of net, so that less water is actually strained in a given time and when towed at a given speed, and also because the less rapid inflow at the mouth of the net will allow the more active rheotropic forms to escape capture. Each of the two types of net gives an imperfect result in one way or the other. Neither "coarse" nor "fine" taken alone will suffice, and it is necessary to use both nets together and add their catches, either actually or mentally, in order to have even an approximate idea of the constitution of the plankton.

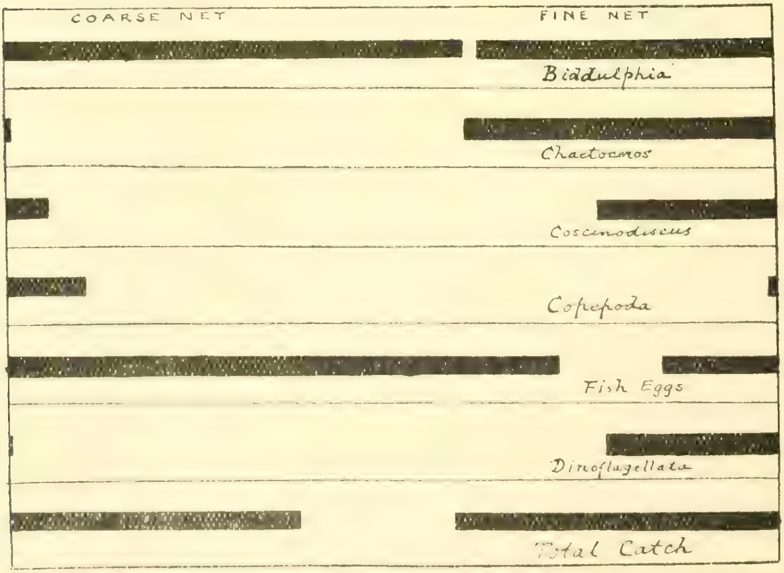

Fig. 11. Comparison of Catches with coarse and fine nets.

The following list shows the amount of the catch in each net on all occasions when both were used together as was made the constant practice at Port Erin during the latter half of April and from September 11th, 1908, onwards.

COMPARISON OF TOTAL CATCH (IN C.C.) OF FINE AND COARSE SURFACE NETS.

Date, &c.				Fine.	Coarse.	Total.
Apr.	16	Stat.	III.	2·25	2·0	4·25
,,	17	Bay		4·5	5·5	10·0
,,	22	,,		7·0	6·5	13·5
,,	22	Stat.	I.	1·2	1·0	2·2
,,	23	Bay		7·0	3·0	10·0
,,	24	Stat.	I.	2·25	2·0	4·25
,,	25	Bay		7·5	6·0	13·5
,,	27	Stat.	I.	3·75	2·0	5·75
,,	27	,,	II.	1·25	3·5	4·75
,,	27	,,	III.	5·0	6·0	11·0
,,	29	,,	III.	11·0	6·5	17·5
,,	29	,,	II.	1·0	4·0	5·0
,,	29	,,	I.	6·0	6·5	12·5
,,	29	Bay.		11·5	8·0	19·5
Aug.	7	Stat.	III.	1·0	6·0	7·0
Sept.	11	,,	I.	0·3	7·5	7·8
,,	11	,,	III.	0·4	5·5	5·9
,,	12	,,	I.	0·4	6·5	6·9
,,	12	Mid.	Ch.	0·2	1·6	1·8
,,	14	Stat.	IV.	0·6	7·0	7·6
,,	14	Bay.		1·5	2·0	3·5
,,	15	Stat.	I.	0·2	4·5	4·7
,,	15	,,	III.	0·7	5·5	6·2
,,	16	Bay		0·6	19·0	19·6
,,	17	,,		0·5	10·0	10·5
,,	19	Stat.	III.	0·5	9·0	9·5
,,	21	Bay		5·5	1·5	7·0
,,	22	,,		1·0	4·0	5·0
,,	24	,,		1·5	6·5	8·0
,,	25	,,		2·0	5·0	7·0
,,	28	,,		0·5	4·8	5·3
,,	29	,,		0·4	4·7	5·1
,,	30	,,		0·8	3·5	4·3
Oct.	1	,,		0·5	4·0	4·5
,,	2	,,		1·0	2·5	3·5
,,	3	,,		0·75	1·7	2·45
,,	5	,,		1·2	1·5	2·7
,,	6	,,		2·0	2·5	4·5
,,	7	,,		2·2	6·0	8·2
,,	8	,,		1·8	9·7	11·5
,,	9	,,		0·4	5·0	5·4
,,	12	,,		1·0	14·5	15·5
,,	13	,,		3·0	6·0	9·0
,,	14	,,		0·75	10·5	11·25
,,	15	,,		1·2	4·0	5·2
,,	16	,,		3·0	3·5	6·5
,,	17	,,		1·0	3·0	4·0
,,	19	,,		0·4	2·2	2·6
,,	20	,,		0·4	3·0	3·4
,,	23	,,		0·3	5·0	5·3
,,	24	,,		0·5	4·0	4·5
,,	26	,,		0·5	4·5	5·0
,,	28	,,		0·75	5·5	6·25
,,	29	,,		0·75	5·5	6·25
Nov.	2	,,		0·8	4·0	4·8
,,	6	,,		0·3	2·0	2·3
,,	10	,,		0·1	2·5	2·6
,,	13	,,		0·4	1·5	1·9
,,	30	,,		0·2	2·0	2·2
Dec.	4	,,		0·1	1·8	1·9
,,	15	,,		0·2	2·0	2·2
,,	23	,,		0·4	2·0	2·4
,,	30	,,		0·8	3·2	4·0

"PULLEY" SURFACE NET.

Both last year and this year we have been struck on occasions, when watching the action of the surface nets in a rough sea, with the manner in which they appeared to bank up the water in front when meeting a wave and then let the line lie slack for a few seconds when the wave had passed - both actions being equally detrimental to that normal and constant straining of the water which is desired. Consequently, when Mr. Drew was assisting in the plankton work on the yacht in August he fitted up one of the surface nets with a pulley fixed to the mizzen-mast in such a way that when the net took the strain of a wave more line was let out to keep the pull as nearly as possible constant, and the line was taken up again as the strain was relieved between two waves. This "Pulley" net was used on all occasions during August when there was any sea running—with the results shown in a column of the table on page 317.

This shows that on most occasions (12 out of 17) the "Pulley" net caught more, and frequently a great deal more (up to more than 8-fold), than the ordinary surface net of the same mesh.

Whether somewhat the same regulating effect upon the pressure of water on the net could be produced by adding a truncated funnel of canvas to the front of the net, like that of the Hensen and other quantitative nets, is worthy of trial; and all the surface and other nets to be used on the yacht at Port Erin during 1909 are now being fitted with such canvas fronts, which will diminish the opening of the net from 15 inches to 6 inches diameter.

COMPARISON OF NEW AND OLD SURFACE NETS.

Kofoid, in his work on the plankton of the Illinois River, found that a new net catches at least 50 per cent.

more than an old one. We met last summer with even a more striking case of the effect of age on the catching power of a net.

COMPARISON OF THE WEIGHT, FINE, COARSE, "PULLEY" AND NEW NETS, AS REGARDS TOTAL CATCH (IN C.C.).

Date, &c.	Fine.	Coarse.	Weight.	"Pulley."	New.
Aug. 4 Stat. I. ...	0·5, 0·8	—	1·5	—	—
,, 4 ,, III. ...	0·8, 0·8	—	1·5	—	—
,, 5 Bay.	1·4, 2·5	—	1·4	—	—
,, 6 Stat. I. ...	0·5	—	0·5	4·3	—
,, 6 ,, III. ...	0·7, 2·6	—	0·8	5·5	—
,, 6 2 miles N.W. of Bradda.	0·6		—	3·1	11·8
,, 7 Stat. I. ...	0·8		0·7	2·8	7·5
,, 7 2 m. off Bradda	1·0	6	—	—	—
,, 8 Stat. II. ...	0·4	—	0·6	2·5	3·0
,, 10 Stat. I. ...	0·4	—	1·6	0·1	2·0
,, 12 ,, I. ...	0·6	—	2·0	0·4	1·6
,, 12 ,, III. ...	1·3	—	2·0	0·6	5·0
,, 12 2 m. S.W. ...	0·2	—	—	—	1·5
,, 13 Stat. I. ...	0·6	—	0·9	0·5	0·4
,, 13 Pecten Bank	0·1	—	—	0·6	0·4
,, 17 Stat. I. ...	0·5, 0·4	—	2·5	—	—
,, 17 ,, A. ...	0·3, 0·2	—	1·0	—	—
,, 18 ,, I. ...	0·6, 1·2	—	1·0	3·2	—
,, 18 ,, III. ...	0·4, 0·3	—	1·8	—	—
,, 19 ,, I. ...	0·7, 1·0	—	1·5	5·3	—
,, 19 ,, V. ...	0·1, 0·1	—	0·8	—	—
,, 20 ,, I. ...	0·7, 0·5	—	0·6	3·2	—
,, 20 ,, III. ...	0·4, 0·2	—	1·0	1·9	—
,, 21 ,, I. ...	2·0, 0·2	—	0·7	—	—
,, 21 ,, IV. ...	2·4, 0·3		1·5	—	—
,, 22 ,, I. ...	0·2		1·0	0·4	2·0
,, 22 ,, III. ...	0·5	—	0·3	0·2	0·1
,, 24 ,, A. ...	0·5, 2·0	—		—	—
,, 26 ,, I. ...	0·3	—	0·8	1·0	1·0
,, 26 Bay	1·4	—	0·6	—	—
,, 28 ,, ...	0·1, 0·5	—	0·3	—	—
,, 31 Stat. I. ...	0·3	—	0·2	—	1·2

At the beginning of the season 1908 all the ordinary plankton nets on the yacht were new, and were made from the same piece of No. 20 silk. So, although well washed down when used, and periodically soaked in fresh-water, they no doubt all got old together and at much the same rate. Early in August one of the two fine surface nets was carried away, and on August 6th a new net which had not yet been used, but was otherwise exactly similar, was brought out to take the place of the lost one, with the result that it at once caught about 20 times as much as the old net and more than three times as much as the "Pulley" net. The column headed "New" in the table above shows how this increased catching power in the new net diminished rapidly from day to day until after being used about nine times, on eight days, it caught much the same as the old net used at the same time. The diagram (fig. 15) brings out this diminishing difference clearly, and shows the catches in the old net keeping at a fairly uniform level, while those in the new net form a rapidly descending curve.

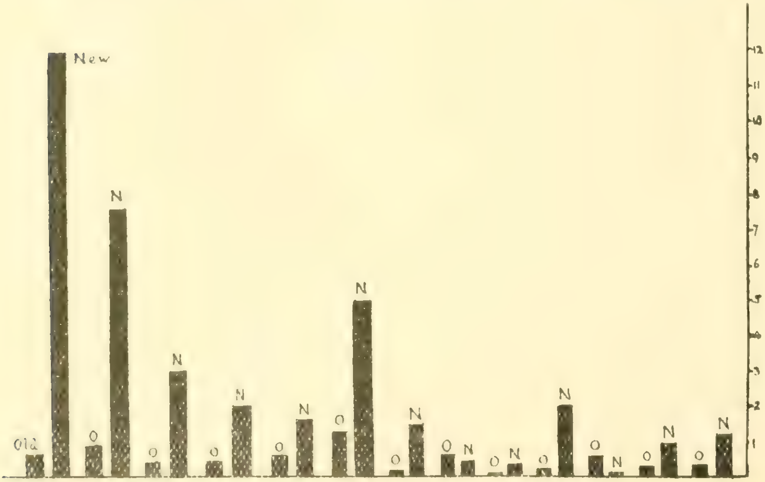

Fig. 15. Comparison of Catches made by Old and New Nets.

Nets thus "age," or diminish in catching power very rapidly; and moreover some types of catch differ very much from others in altering the filtration coefficient of the net—for example, a net may have its meshes so clogged by an abundant haul of Medusae, or *Phaeocystis*, or *Chaetoceros*, that it will only let the water through very slowly even when suspended in air. Such a net cannot have been filtering satisfactorily during its last haul, and it is very difficult to get the meshes thoroughly cleaned. The filtration coefficient of a net must thus vary not only with age, but to some extent with every individual catch that is made, and even possibly with the effect produced by previous catches.

SURFACE AND DEEPER NETS.

On the whole, the results obtained in 1908 confirm those noted in the report for 1907. Again the weight net (in all other respects agreeing with the fine surface net) lowered to a depth of about ten fathoms and gradually rising to a depth of a fathom or two below the surface, gave in most cases a larger haul than the similar surface net. The various points mentioned in last year's report could again be exemplified from the 1908 forms; but it seems unnecessary to repeat what has already been demonstrated.

Form No. **10** is rather interesting, as showing a contrast between the surface and the deeper nets at a point just outside the bay to the north. It also shows a haul taken on the same day inside the bay, and illustrates what is often seen, namely, that the plankton is larger in amount inside the bay than outside. The surface net *in* the bay obtained as much material as the weight net outside. It will be noticed that few Dinoflagellata were obtained in the weight net, and that more were present inside the bay than outside. It is also noticeable that no adult Copepods were obtained on this occasion *in* the bay, while all three nets outside obtained some.

Form **23**, dealing with the gathering taken off

Niarbyl on April 20th, shows what we consider to be the usual proportion between the catches taken by the different nets—the two surface nets giving about 4 c.c. each, the weight net about 12 c.c. and the shear net about 20 c.c., while the Hensen and Nansen vertical hauls give about 1 c.c. each, the Nansen rather more than the Hensen. On looking at the constitution of the catches, it is interesting to find how closely the numbers of the individual species in most cases correspond in the two surface hauls, being in quite a number of cases absolutely identical. Then, again, the Hensen and the Nansen hauls correspond fairly well, amounting to absolute identity in the number of Copepoda. The increase in quantity in the weight net is due in the main to the greater number of Copepoda caught, and to a swarm of *Evadne* which this net alone seems to have encountered. The contrast between the shear and the other nets is typical, all the smaller organisms being absent or represented by a few retained accidentally, while the bulk of the gathering is due to such larger things as Medusae, Sagitta, Larval Polychaeta, Crabs and Shrimps, along with a few of the larger Copepoda and some post-larval fishes. The shear net also caught most of the fish eggs, the total being 133, as against 20 taken by the surface net which caught most, and the same number in the weight net.

Three days later we returned to the same spot, and worked the same set of nets with very much the same results, the numbers being:—Surface nets, 4 and 3 c.c.; weight net, 5 c.c.; shear net, 19 c.c.; Hensen, 0·5 c.c.; and Nansen, 1 c.c. The chief difference here is that the weight net caught less compared with the surface and the vertical nets. Of course, the hauls in the two days differ a little in detail; but the striking point is the similarity in general character, and sometimes even in the

10.—Off the Carron, Bradda, April 13th, 1908.

Net used	Surface.	Surface.	Weight.	Surface in Bay.
Depth in fathoms	0	0	—	0
Catch in c.cm.	2·3	2·5	4·5	4·5
Asterionella bleakeleyi	3,000	—	750	2,500
,, japonica	1,000	—	—	—
Biddulphia mobiliensis	100,000	105,000	120,000	145,000
Chætoceros contorum	—	—	750	3,750
,, debile	10,000	—	17,250	12,500
,, decipiens	12,500	1,000	5,250	3,750
,, sociale	500	—	3,000	1,000
,, teres	10,000	2,000	11,000	27,000
Coscinodiscus concinnus	10,000	5,000	18,750	20,000
,, radiatus	98,000	28,000	42,000	99,000
,, grani	—	—	—	700
Coscinosira polychorda	1,000	—	—	—
Ditylium brightwellii	—	—	500	2,500
Rhizosolenia semispina	—	—	—	3,750
,, shrubsolei	1,000	500	—	1,000
Thalassiosira gravida	500	—	700	1,000
,, nordenskioldii	500	—	—	1,000
,, subtilis	500	500	—	—
Leptocylindrus danicus	500	—	—	—
Guinardia flaccida	3,000	500	500	2,500
Streptotheca thamensis	—	500	500	—
Lauderia borealis	—	—	—	2,500
Ceratium furca	—	—	—	700
,, fusus	—	500	—	1,000
,, tripos	—	1,000	750	700
Peridinium	—	—	—	700
Tintinnopsis sp.	—	—	—	3,000
Pleurobrachia pileus	1	—	—	—
Medusoid gonophores	—	—	—	20
Sagitta bipunctata	—	3	6	1
Autolytus prolifer	—	2	—	—
Larval polychæta	1,500	5	—	3,800
'Mitraria'	—	—	500	—
Crab zoea	—	—	10	4
Mysis stage of Crangon	—	—	—	2
Pseudocalanus elongatus	130	110	750	—
Temora longicornis	10	5	34	—
Acartia clausi	10	10	60	—
Oithona similis	5	—	20	—
Copepod nauplii	12,500	7,500	9,000	37,500
,, metanauplii	—	—	—	100
,, Juv.	500	1,000	1,500	1,250
Cirripede nauplii	130	175	320	175
Gasteropods, larval	—	—	—	1,000
Lamellibranchs, larval	500	—	750	1,000
Oikopleura sp.	10	—	20	25
Fish eggs Rockling	3	6	2	8
,, Dab	1	1	—	3
,, Dragonet	—	—	1	1
,, Topknot	—	—	1	—
,, Whiting	—	—	3	—
,, Flounder	—	—	—	1

23.—Off Niarbyl, April 20th, 1908.

Net used	Surf.	Surf.	Hensen.	Nansen.	Weight.	Shear.
Depth in fathoms	0	0	20-10	20-10	10	10
Catch in c.cm.	4·5	3·5	0·8	1·2	12·5	20
Asterionella bleakleyi	750	750		—	1.500	—
„ **japonica**	750	750	—	200	1.500	—
Biddulphia mobiliensis	87.750	90.000	3.450	4.400	82.000	750
Chætoceros contortum	1.500	1.000	75	100	3.000	-
„ debile	127.500	120,000	4.300	11.500	300.000	75
„ **decipiens**	7.500	7.000	300	500	9.000	-
„ sociale	—	—	75	200	3.000	--
„ teres	60.000	55.000	3.100	4.000	75.000	75
Coscinodiscus concinnus	9.000	8.500	375	600	3.000	—
„ **radiatus**	26,250	25,000	1,000	1.700	45.000	675
Ditylium brightwellii	2.250	2,250	75	—	4.500	—
Rhizosolenia setigera	750	750	—	—	500	—
„ shrubsolei	750	750	- -	—	1.500	—
Lauderia borealis	750	750		100	1.500	—
Guinardia flaccida	3,000	2,750	75	100	1.500	—
Nitzschia seriata			150	100	1.500	—
Tintinnopsis sp.	3.000	3.000	-		4.500	-
Ceratium furca	2.250	2.000	—	-	1.500	--
„ fusus	750	750	—	—	500	—
„ tripos	750	750	—	100	500	—
Peridinium	750	900	-	-	1.500	---
Medusoid gonophores			2	—	2	150
Plutei of Echinoderms	750	750	75	—	-	—.
Sagitta bipunctata	5	2	2	2	-	200
Larval Polychæta	-	-	150	---	—	865
Crab zoea	3	2	1	—	16	410
Mysis stage of Crangon	—	—	—	1	10	400
Evadne nordmanni	-	—	—	—	1.000	—
Calanus helgolandicus	—	—	—	-	--	5
Pseudocalanus elongatus	15	25	55	55	1.360	10
Temora longicornis	10	10	5	5	100	5
Acartia clausi	50	30	10	10	40	15
Oithona similis	—	5	5	5	20	--
Paracalanus	5	—	—	-	—	—
Copepod nauplii	1.500	—	150	200	4.500	-
Cirripede nauplii	975	125	80	75	900	1.300
Lamellibranchs, larval	750	750	—	—.	1,500	--
Oikopleura sp.	5	5	5	5	60	225
Fish eggs Rockling	12	11	-	—	8	15
„ Haddock	1	2	—	—	2	15
„ Whiting	2	—	—	—	3	90
„ Bib	1	—	—	—	—	—
„ Dragonet	3	2	—	—	5	—
„ Dab	1	—	—	—	2	-
„ Grey Gurnard	—	-	—	—	—	3
„ Plaice	—	—	--	—	-	10
P.L. fishes, Pleuronectid	2	—	1	1	—	—
„ Gadoid	—	—	—	—	—	20
„ **Clupeoid**	—	—	—	—	—	70

actual numbers, showing that when the plankton is the same the nets we use show this. Again the shear net caught most of the fish eggs and nearly all the young fishes (320 Clupeoid and 10 Gadoid).

The adjoining table, which gives certain hauls taken from Forms **25**, **26** and **30**, shows a comparison between Station I and Station II on April 22nd, and the surface nets in the bay on April 24th. This comparison brings out the fact, seen also on other forms, that the surface plankton is often more abundant in the bay than at the offshore Stations. In this case it gives fully as large a haul as the "weight" net at Station II, and about four times as much as the average of the four surface gatherings taken in the open sea.

It will be noticed that in the bay, while Diatoms are abundant, Dinoflagellata are entirely absent: at Station I they are present to the number of a few hundreds of each species in each net; while at Station II most of the nets have a thousand or two of each species. The Diatoms are less abundant at Station I than at Station II, and much less abundant at both offshore Stations than in the bay. The "weight" net has not more Dinoflagellata and not more Diatoms than one of the surface nets, and the greater bulk of its gathering is due to larger organisms, such as Sagitta, Copepoda and larval Lamellibranchs. There were on this occasion no fish eggs except Rockling in the bay.

"PLANKTON-RÖHRE."

With the view of ascertaining whether there was much regularity in the catch obtained from a very small quantity of water collected continuously over a wide extent of sea, a German Plankton-Röhre (Apstein's) was obtained, late in August, from Zwickert's at

25, 26, 30.—April 22nd and 24th, 1908.

	Station II.			Station I.		P. Erin Bay.	
Net used	Surf.	Surf.	Weight.	Surf.	Surf.	Surf	Surf.
Depth in fathoms	0	0	10	0	0	0	0
Catch in c.cm.	1·5	3	6	1·2	1·2	6·5	7
Asterionella bleakeleyi	500	2,000	—	—	—	2,000	2,000
„ japonica		—	—		—	2,000	2,000
Biddulphia mobiliensis	14,000	7,000	11,000	40,000	30,000	41,000	45,000
Chætoceros contortum	1,000	5,000	5,000	—	—	34,000	38,000
„ debile	50,000	126,000	100,000	20,000	11,500	378,000	400,000
„ decipiens	21,500	26,000	12,000	5,500	2,000	13,000	20,000
„ sociale	4,000	3,000	3,000	500	500	—	—
„ teres	48,000	100,000	80,000	24,000	17,000	110,000	150,000
„ criophilum	500	2,000	1,000	200	—	—	—
„ boreale	500	500	—	—	—	—	—
Coscinodiscus concinnus	3,000	3,000	2,000	2,000	3,000	3,000	3,500
„ radiatus	4,500	10,000	6,000	13,000	12,500	23,000	24,000
Coscinosira polychorda	500	1,000	1,000	—	—	8,000	10,000
Ditylium brightwellii	500	500	—	250	250	2,000	200
Eucampia zodiacus	—	—	1,000	—	—	500	500
Rhizosolenia semispina	500	1,000	1,000	—	—	3,000	3,000
„ shrubsolei	—	—	1,000	—	—	500	500
Thalassiosira gravida	500	—	500	—	—	1,000	1,000
„ nordenskioldii	3,500	5,000	4,000	—	—	2,000	3,000
Lauderia borealis	1,000	2,000	4,000	—	—	6,000	10,000
Streptotheca thamensis	500	—	—	250	500	1,000	1,000
Guinardia flaccida	1,000	—	2,000	750	1,000	2,000	4,000
Acnanthes taeniata	—	—	—	—	—	4,000	6,000
Bacillaria paradoxa	—	—	—	—	—	3,000	3,000
Tintinnopsis sp.	—	—	—	250	250	4,000	—
Ceratium furca	1,000	2,000	2,000	500	500	—	—
„ fusus	—	800	2,000	250	250	—	—
„ tripos	1,000	2,000	2,000	250	500	—	—
Peridinium	500	2,000	500	250	250	—	—
Medusoid gonophores	4	30	55	6	—	—	3
Plutei of Echinoderms	250	—	—	—	—	—	—
Autolytus prolifer	—	—	—	—	—	1	—
Sagitta bipunctata	—	—	4	—	—	3	2
Larval Polychæta	—	—	—	—	—	575	100
'Mitraria'	250	—	100	—	—	—	—
Crab zoea	—	—	8	2	1	14	25
Mysis stage of Crangon	—	—	3	—	—	2	4
Evadne nordmanni	25	—	—	—	—	—	—
Calanus helgolandicus	—	—	1	—	—	—	—
Pseudocalanus elongatus	10	180	1,660	—	—	140	150
Temora longicornis	5	10	50	1	—	15	30
Centropages hamatus	—	—	—	—	1	—	—
Anomalocera pattersoni	45	10	10	—	2	—	—
Acartia clausi	125	10	100	30	28	10	20
Oithona similis	—	—	—	1	—	—	—
Copepod nauplii	1,500	7,000	18,000	250	500	3,000	4,000
„ Juv.	500	1,000	2,000	—	—	2,000	2,500
Cirripede nauplii	—	—	30	1	—	1,450	500
„ cypris stage	—	—	—	—	—	—	1
Gasteropods, larval	—	—	—	—	—	250	250
Lamellibranchs, larval	—	—	1,000	2,250	1,500	250	250
Oikopleura sp.	25	25	160	200	—	10	10
Fish eggs Rockling	24	14	14	9	5	2	1
„ Bib	8	—	—	2	15	—	—
„ Haddock	6	10	5	4	6	—	—
„ Cod	4	10	11	8	4	—	—
„ Whiting	12	5	3	5	13	—	—
„ Dab	3	1	—	1	9	—	—
„ Topknot	—		—	1	1	—	—
„ Dragonet	—	—	—	3	1	—	—

Kiel, and was towed behind the ship, at a rate of about 8 knots, whenever we made a run of five miles or so without stop. On each such occasion the piece of No. 20 silk from the "Röhre" was plunged direct into a small bottle of formol solution, and the catch was obtained from it afterwards. The opening of the Röhre by which water enters is only 1 cm. in diameter, the length of the brass tube is about 25 cm., and the silk-covered wider opening is 3·5 cm. in diameter.* The results of the nine hauls, for at least the leading groups of organisms, are given in the table, and the most noteworthy feature is the comparative uniformity both in total catch and in the numbers of most of the organisms.

60.—PLANKTON-RÖHRE CATCHES.

Date.		Total Catch.	Diatoms.	Dinoflagellates.	Copepoda.			Oikopleura.
					nauplii.	juv.	adult.	
Aug.	21...	0·2	175	1,400	1,425	325	736	—
,,	22...	0·2	100	1,945	1,500	100	423	40
,,	24...	0·1	25	1,400	750	50	101	9
,,	26...	0·2	—	250	1,000	125	128	5
,,	26...	0·2	—	1,125	1,780	200	158	4
,,	31...	0·2	100	225	550	100	132	60
Sept.	12...	0·05	38	90	188	112	59	—
,,	15...	0·1	175	200	425	50	130	2
,,	18...	0·1	38	313	375	112	102	1

CONCLUSIONS.

This section may be brief. It is unnecessary to repeat at any length what was given in Part I. last year, and there is a good deal of detailed analysis that we prefer to retain for a further Part when we have additional evidence and another year's experience of the work. We have collected, and have printed in this Report, a good deal of evidence from which we have as yet drawn no conclusions; and we have made out many lists, curves and other diagrams which we have kept back for fuller consideration in the light of further experiments. We have placed on record what we have been able to ascertain in regard to the local winds, tides and sea-temperatures, in the hope that these facts may be of use in further discussion of the occurrence and distribution of plankton in the Irish Sea.

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* For description and figure, see Dakin, "Methods of Plankton research," Trans., *Liverpool Biol. Soc.*, Vol. XXII, p. 538.

Although this second year (1908) has differed a good deal in details from 1907, still certain broad series of facts are common to the two years.

(1) We again find that the Diatoms predominate in spring and, to a less extent, in late autumn, and are practically absent in summer.

(2) We again find that while fish eggs and many other organisms (when present) occur in units and tens in an average haul of our nets, Copepoda generally run to hundreds, Dinoflagellates to a few thousands, and Diatoms into tens of thousands, or anything between that and millions.

(3) From the inspection of the Forms recording the catches we again get the impression that much the same organisms are present in the different nets at the one time of year in somewhat similar proportions, so that although it is possible to discuss the general character of the fauna and the relative abundance of different groups, it is not possible to use the numbers as the basis of calculations as to the quantity of any group, or of living things as a whole, in any large area of the sea at a particular time—the results arrived at might easily be 50 per cent. wrong in either direction.

(4) We again find that the shear net, or any larger

wide-meshed net, such as the Yngel-trawl, catches far larger quantities of the larger organisms, and fewer of the smaller forms such as Diatoms and Dinoflagellates and the more minute Larvae. After the evidence that we quoted last year from the Forms, it is unnecessary to say more than that that result has been corroborated again by this year's work.

(5) We find again that, except on a few occasions, the weighted net working in a deeper zone obtains a larger catch than the surface nets, and that, on the whole, the most populous layer in the water is a few fathoms below the surface.

(6) Again the Nansen net, worked vertically through the zone from 20 up to 10 fathoms, invariably catches more than the Hensen net under the same circumstances, and in the April hauls, at Station I, may have as much as ten times the quantity of Diatoms. In some cases the Hensen net shows clearly an increase of catch on being hauled up through a more superficial zone than the usual 20-10 fathoms; but in other cases it does not. For examples of the former, which we regard as the normal state of affairs, take:—

April 24.	Station	I—20-10	faths.	=	9.175 ;	20-0	faths.	=	18,050
,, 29.	,,	III 10-5	,,	=	35,065 ;	10-0	,,	=	43,750
August 20.	,,	I—20-10	,,	=	400 ;	10-0	,,	=	800
September 15.	,,	I—20-10	,,	=	1,080 ;	20-0	,,	=	2,650

The increased catch seems due not merely to the increase of distance, but to the fact that above 10 fathoms the net enters a more populous zone (see August 20th, above); while April 29th supports the view that 10-5 fathoms has a richer fauna than the water above.

(7) The general result this year is that the spring and autumn maxima of Diatoms are distinctly later, and are also less marked than in 1907. The maxima of the

Dinoflagellata in the bay were about a month later in 1908, but they attained a higher level. The Copepoda on the other hand did not reach so high a point in the bay this year. For further details in regard to these, and also as to the occurrence of other groups compared with the previous year, reference must be made to the body of the Report.

(8) Some points which might vitiate results have occurred to us in the course of our work, or have been suggested by critics. These we shall now briefly consider.

1. The difference between the two sides of the ship.—It has been suggested that similar nets hauled simultaneously on the port and starboard sides may differ in catch because of the disturbing effect produced by the boat upon the surface water and its contained organisms. No doubt when the ship is broadside on to any wind, tide or sea the windward and leeward sides might yield somewhat different hauls in the surface nets; but such conditions were not present in our experiments. The surface nets were towed close together over the stern, and the boat was kept head to wind and sea; consequently the nets were never one to windward and one to leeward, and both received the same amount of exposure or shelter as the case might be. It was only when using the vertical nets (Hensen and Nansen) hauled up from deeper strata that one was worked on each side of the ship, which was then kept as nearly stationary as possible with her head to the sea or wind, and in these cases, as the nets were generally used to collect samples of the deeper strata only and were closed at ten fathoms from the surface, any disturbance of the surface fauna due to the ship would not affect their catch.

2. The effect of the ship's screw-propeller upon the catch of nets towed astern.—In a review of Part I

of our work which appeared in "*Internationale Revue der Gesamten Hydrobiologie und Hydrographie*" for December, 1908, by Prof. C. A. Kofoid, the reviewer suggests "that possibly the two nets towed aft the boat were, owing to the swirl caused by the propeller, probably straining water which in the undisturbed sea was at different levels, and that their catch represents the plankton not of the upper two feet but of a considerable, and for the two nets probably different, radius below this level" (*loc. cit.*, p. 846).

In a private letter to one of us, Prof. Kofoid again raises the same point, and adds:—"At a distance of 50 feet behind the vessel it is quite possible that the diameter of the moving mass would be over 8 feet—as surface water is stirred and presumably the deeper layers to a slightly less distance . . . . These limits are just such as might well make the difference between a catch with many worm and Crab larvae and adult Copepoda, and one without—under certain conditions of light or time of day."

In our steamer the diameter of the propeller is 4 feet, and when one of the four blades is vertical its top is just 2 feet below the water line in a calm sea. So the water is stirred up directly by the propeller blades to a depth of 6 feet below the surface, and indirectly, no doubt, for some little distance below that; but whether organisms would be brought up to the surface nets from a greater distance than, say, a fathom and a half is probably doubtful; and whether stirring up to that depth will make a difference in the catch is also questionable. Still these are all points that ought to be cleared up by experiment, and we propose to deal with them in the coming season, and to compare, for example, the catches in nets towed some little way off the side of the ship with similar nets towed behind.

If the catch in nets over the stern is seriously affected by the action of the propeller, then it is difficult to account for the great similarity of the catches in these nets on some occasions—as, for example, on April 22nd, 1907, when Form **45**, which was quoted in last year's report, shows that the two surface nets at Station IV caught precisely the same amount of material, and where the lists of organisms constituting the catch were almost exactly alike, both in species and numbers. Such a close agreement can scarcely be explained otherwise than as due to similar sampling of similar populations. That it cannot be due to an unusual condition where the surface and the deeper zones are at the time alike in population is shown by the fact that the weight net on the same occasion brought up a catch which differed from the two surface hauls.

3. In Part I of this investigation last year, we arrived at the conclusion that the constitution of the plankton from time to time throughout the year is due to the interaction of three factors:

(1) The sequence of the stages in the normal life-history of the different organisms.
(2) Irregularities introduced by the interaction of the different organisms.
(3) More or less periodic abnormalities in either time or abundance caused by the physical changes in the sea which may be grouped together as "weather."

Prof. C. A. Kofoid, in his review referred to above (*Internat. Rev. Hydrobiol. und Hydrogr.*, December, 1908, p. 845), seems to find some inconsistency in the use of the first and the last of these factors. In case Prof. Kofoid, and possibly others, have not entirely understood our meaning, we should like to try to make our position clear by means of an example and a diagram.

Let us suppose that the line A . . A (in fig. 16, I.) is the normal and undisturbed curve representing the life-history throughout the year of the population of that organism in a particular locality. It is a small population early in the year, increases to a maximum in summer, and dies down again in winter. That curve represents the effect of our first factor alone. Some organisms may show such a curve under some circumstances, but it is probably much more usual for the curve to be affected by the two other factors in the following manner. The line BB may represent, diagramatically, the inroad made upon the supposed population by natural enemies. That is an example of the action of our second factor, and such

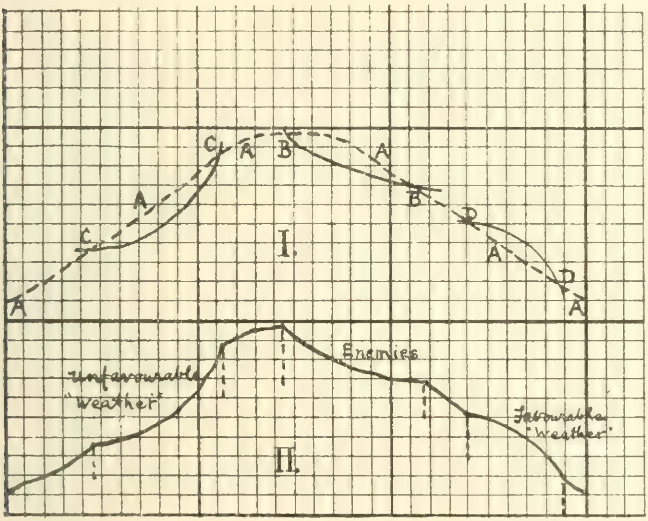

FIG. 16.—I., A......A, supposed curve of normal life-history disturbed by the influence of enemies, "weather," &c.
II., the resulting curve due to the effect of all the factors.

encroachments may be great or small, may be confined to certain periods of the year, or may be continuous so as to reduce the original curve more or less along its whole length. Finally, the lines CC and DD may indicate the manner in which unusual "weather" conditions (under which we include changes in salinity and temperature of the water as well as any unusual currents, storms, sunshine, &c.) may retard (as at C in spring) or prolong (as at D in late autumn) the normal increase in the population.

The resulting curve due to the combination of all these factors in this supposed case would then be as shown in fig. 16, II. Whether it may eventually be possible from a consideration of all the environmental conditions, and the comparison of different years, and different localities, to disengage from one another the action of these three factors, so as to be able to predict what the effect of weather (in the widest sense) may be upon the normal plankton supplies and upon the Fisheries of any sea-area is quite another question, and one which without much further experiment and comparison of results under varying conditions cannot yet receive any definite answer. But the problem does not seem so complicated as to forbid all hope of ultimate analysis and solution, and consequently it seems desirable that the work should be vigorously prosecuted in as many localities as possible, not as an aimless collection of statistics, but as a definite experimental research.

L.M.B.C. MEMOIRS.

No. XVII.—PECTEN.

The Edible Scallop.

BY

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INTRODUCTION.

Although the greater part of the following account of this type applies to the anatomy and histology of *Pecten maximus*, the very common smaller species *P. opercularis* has also been investigated. Some details in which the latter differs from *P. maximus* are mentioned in the text, but, on the whole, these differences are but slight, and either species may be dissected and examined while using this Memoir.

The work has been carried out chiefly in the Zoology Department of the University of Liverpool and at the Port Erin Biological Station, Isle of Man. The chemical work was done at Larne, Co. Antrim, and some of the observations on the sense organs at Kiel. My thanks are due to Professor Herdman for his valuable advice, and for aid in obtaining living material by dredging at Port Erin; also to the Larne Aluminium Company for permission to use their chemical laboratory; and finally to Mr. Chadwick, Curator of the Port Erin Biological Station.

TAXONOMY AND DISTRIBUTION.

Pecten maximus and *P. opercularis* are two of the common British species of the genus *Pecten*, and are known in some places as "scallops." Pecten is the most familiar genus of the family Pectinidae, the correct position of which amongst Pelecypoda or Lamellibranchiate Molluscs is not easy to determine. The shells, gills, muscles, mantle, siphons, &c., have all been employed in classifying the Lamellibranchiata, but, so far, without really satisfactory results. The following classification proposed by Pelseneer (**7**), and founded on the structure of the gills, appears to be the most reliable.

Protobranchia Lamellibranchia possessing gills with flat and non-reflected filaments disposed in two rows on opposite sides of the branchial axis.

Filibranchia—With gills formed of parallel, ventrally directed, and reflected filaments. The successive filaments are joined together by cilia disposed in "ciliated discs."

Eulamellibranchia—In which the gills and branchial filaments are united at regular intervals by vascular junctions.

Septibranchia—Dimyarian Lamellibranchs in which the mantle remains fairly open, the gills have disappeared as respiratory organs and have been transformed into a muscular septum dividing the pallial cavity into two chambers.

Ridewood (**12**) keeps the first of these orders as it stands, but divides the remaining Lamellibranchs into only two orders, as follows:

Ord. I.—Protobranchia (as above).

Ord. II.—Eleutherorhabda. This is practically the same as the Filibranchia.

Ord. III.—Synaptorhabda. This includes Pelseneer's two orders, Eulamellibranchia and Septibranchia.

Thus according to both these classifications, the older group, Pseudolamellibranchia is done away with. This order included the Pectinacea and the Ostraeacea: the first of these has been removed to the Filibranchia and the second to the Eulamellibranchia.

We see, therefore, that the position of our type is as follows:—

Class: Lamellibranchia. Ord.: Filibranchia. Suborder: Pectinacea. Fam.: Pectinidae. Genus: Pecten.

The American scallop, however, *Pecten tenuicostatus*, has, according to Drew (**1**), the gill filaments united by interfilamental vascular junctions, thus forming one exception to the definition of the Filibranchia, and serving to show how insufficient single characters may be in a scheme of classification.

The genus Pecten is of world-wide distribution, though most of the species are confined to smaller areas, and the habitat extends from the littoral zone down to the 450 fathom line and probably further.

The distribution in time extends from the Cretaceous, and possibly it goes even further back to the Carboniferous period. Jackson (**3**) in his work on the Phylogeny of the Pelecypoda, has shown how this genus is related by the structure of the early nepionic shell to the Aviculidae, and in all probability the fossil Aviculopecten of the Devonian rocks was a connecting link, so that the ancestry of the Pectens can thus be traced back to Silurian times.

In addition to *Pecten maximus* and *P. opercularis*—generally distributed in European seas—the following species are found round the British coast:—*Pecten pusio* (Linné), *Pecten varius* (Linné), var. *purpurea*, Jeffreys, and var. *nivea*, Macgillivray, *P. sulcatus* (Müller), *P. fragilis* (Jeffreys), *P. clavatus*, var. *septemradiatus*, Müller, var. *alba*, Jeffreys, and var. *dumasi*, Payraudeau, *P. tigerinus* (Müller), and var. *costata*, Jeffreys, *P. incomparabilis* (Risso), *P. striatus* (Müller), *P. similis* (Laskey), *P. vitreus* (Chemnitz), *P. grœnlandicus*, Sowerby, and four varieties of *Pecten opercularis* var. *lineata*, da Costa, var. *tumida*, Jeffreys, var. *elongata*, Jeffreys, and var. *audouini*, Payraudeau.

For systematic descriptions of these species and varieties reference should be made to Forbes and Hanley's "British Mollusca," and Jeffreys' "British Conchology."

Both *P. maximus* and *P. opercularis*, but especially the latter, are gregarious; and in various places round the British Coast beds of scallops exist where *P. opercularis* can be obtained in thousands by dredging. Both species prefer a sand or gravel bottom, but sometimes they occur on mud. The depth of the great bed of *P. opercularis*, situated off Port Erin at the South-west end of the Isle of Man, is about 17-22 fathoms, and all the specimens of both species used in preparing this Memoir came from an average depth of about 20 fathoms.

BIONOMICS.

The animal is found lying free, neither adherent by the shell nor by a byssus. Locomotion, however, is carried on, not by the usual Lamellibranch methods of creeping or leaping, but by spasmodic swimming. This is one of the most interesting peculiarities of the genus, and, moreover, certain features in the anatomy of the mollusc have, in all probability, been modified owing to this habit. *Pecten opercularis* swims much more frequently and for a longer period than *P. maximus*, and if specimens are kept in aquarium tanks, it is quite easy to follow their movements and make out the structures involved in this curious method of progression. It strikes one at once that, contrary to what might be expected, the animal moves with the ventral edges of the shell foremost. The mollusc, which has been lying on one of its valves, causes the shell to open and close in a very rapid manner, and it might be thought that at each sudden clapping of the two valves, the water between them would be forced out ventrally and that the animal in consequence would move with the hinge line foremost. The free or ventral border of the valves is, however, directed forwards in swimming, and the animal seems to take a series of bites at the water.

As will be subsequently described, the valves in both species are not mirror images of each other. *Pecten maximus* has the right valve very much more convex, while the left is quite flat. In *P. opercularis* the two valves are much more alike but the right is slightly less convex than the left. *Pecten maximus* lies on the convex valve or right side, and the flat side is, therefore, superior, and is generally covered with barnacles, serpula, zoophytes, &c. *P. opercularis* also shows by the attached animals being found always on the same side, that it lies on the right valve. If a specimen is turned over on to the other side, it will make efforts to turn back, and usually regains its normal attitude in a few minutes. The two diagrams in text (fig. 1) show that while the two species both lie on the right valve, in one case the more convex side is downwards, and in the other, upwards.

If the undisturbed animal is watched as it opens the valves (which it does very slowly), the tentacles (Plate II., fig. 1, *Tn.*) will first be seen gradually protruded, then the eyes will become obvious, and lastly, when the valves are some distance apart, the two free edges of the mantle (which previously lay against the mantle lobes proper) move outwards until they stand almost at right-angles to the plane of the valves, so as to form one curtain or "velum" (fig. 1, *V.*) hanging from the upper valve and one projecting up to meet this from the lower valve.

In the resting condition the valves of the shell are opened very considerably, but the organs in the pallial cavity cannot be seen owing to the fact that the edges of the upper and lower vela are just in contact. By putting a few grains of carmine in the sea water, an inhalent current can be demonstrated. This enters the pallial cavity by passing between the mantle lobes all round the margin of the shell except for a small distance posteriorly. Here there is a strong exhalent current, and thus, although no morphological siphons are present, there are well-defined areas for the inhalent and exhalent respiratory and nutritive currents.

When the animal is about to swim, the following changes take place: the valves slowly open, that is, they move further apart than in the resting condition, and the visceral mass can be seen between the mantle edges. At the same time the two vela lie slightly turned back against the mantle lobes as if moved inwards by the inflowing water due to the divarication of the valves. Towards the end of this opening motion the tentacles are quite suddenly retracted all round the mantle edge, and immediately the shell shuts with a snap. Just at this moment, however, the two vela take up the vertical position, with their margins touching, and by means of their muscular structure retain this position, acting as a perfect barrier to the water which must escape from the pallial cavity. The result is that the water escapes only where the two vela are not well developed, and where they do not dam back the current, and this is on each side of the dorsal edge of the shell.

There are, therefore, two jets of water shot out dorsally at each sudden closing of the shell, for the process above described is repeated rapidly for several seconds, and consequently the animal moves onward with the ventral margin foremost. An inclination to one side or the other can be effected by partial closure of one of these dorsal openings.

The sudden retraction of the tentacles is always the signal for the closing of the shell.

The animal can, in addition, force the water out at the ventral margin by not bringing the pallial barrier into play. This occurs when it is suddenly stimulated, and then it darts away with the hinge line foremost. It also is interesting to note that when the animal is turned over on to the upper side, it rights itself in a very short time by driving water out sharply between the ventral margins of the shell. This forces the hinge line back against the ground and is then used as a fulcrum on which to turn over. When in the normal position, that is, lying on the convex valve, a slight jet of water sent out ventrally causes that edge of the shell to rise from the bottom, so that the normal movements of swimming can take place without any hindrance from friction with the bottom.

The equilateral character of the shell of Pecten is, perhaps, a modification due to the development of the power of swimming and we may also put down to this, the evolution of a muscular velum, the large single adductor muscle with its adaptations for rapid contraction, and also the large internal cartilage for opening the shell.

It is doubtful whether adult *Pecten maximus* or *P. opercularis* ever employ the foot for purposes of locomotion. This seems to be rudimentary in the adult as far as its use as a locomotive organ is concerned, but as on one occasion I was able to see a *P. maximus* protrude its foot —which is evidently capable of much distension—out of the shell, it may be possible that in its normal habitat it uses the foot more frequently. I have not been able to examine the very young stages of *P. maximus*, but *P. opercularis* and *P. irradians* of the American coast have a period before the free stage is reached, when they attach themselves by means of a byssus.

In a still earlier stage after the free-swimming larva has settled down, the animals are unattached and crawl about actively. The foot is protruded, attached to some object and then contracted, and in this way the animal is pulled along by successive attachments and contractions of the foot. The foot of the adult Pecten is very like a sucker, though in no case have I seen it used in the manner above described.

Following the crawling stage we have the byssus stage, and the foot takes part in the attachment of the threads.

Jackson (**3**), who has watched the American species, describes it as follows:—"Lying on the right valve, the foot is extended on the surface of the dish, the flattened distal portion taking a firm hold as if about to crawl. This position is maintained for a moment or two and then the foot is withdrawn within the body, by the motion of retraction it draws out, or spins, the byssal thread, which the creature had fixed to the surface of the dish while the foot was laid closely against it. Soon the foot is again extended, pressed flatly against the dish and another byssal thread is spun, three is the common number with specimens in confinement."

If disturbed the attached scallop can break or cast off its byssal threads and swim by clapping its shell. The adult *P. opercularis* only occasionally shows any signs of the byssus, but *P. varius*, another common British species, is usually attached.

Pecten feeds largely on vegetable matter, such as diatoms, fragments and spores of algae, together with the smaller micro-crustacea suspended in the inhalent current which is continually passing between the mantle lobes. This current is set up by the cilia on the gills and palps, the water is filtered by means of the gills, and the microscopic matter is entangled in mucus and conducted to the mouth.

The foot is a great mucus-secreting organ, and the labial palps and lips direct the food current to the mouth opening.

When dredging on Pecten grounds, empty shells are frequently dredged up, which are neither old nor have the appearance of having been unoccupied for long. It is probable that starfish, together with the whelk, are accountable for some of these empty shells. A large dog whelk in Port Erin aquarium had killed and partially eaten a *P. maximus* by getting the anterior end of its shell between the separated valves of Pecten, and then attacking the adductor muscle with its proboscis.

Parasites are very scarce, no internal ones having been met with in any of the specimens sectioned. *Lichomolgus maximus* (**8**) is, however, an interesting ectoparasitic copepod which may be obtained by washing in sea water the gills and mantle to which it adheres. It is of an orange colour, very like that of the gills, and, so far, has only been found in *P. maximus*, from which the specific name is taken.

Very often the shells of Pecten are bored through by *Clione celata* (a boring sponge). This ramifies extensively between the outer and inner layers of the shell, and gives off short shoots which pass outwards to the external and internal surfaces of the valves. At the points where these tubes perforate the internal layer of the shell, the mantle secretes calcareous nodules of a dark grey or black colour.

The outer surface of the upper valve forms, as one would expect, a good platform for such sessile animals as Balanus, Zoophytes, Serpula, &c.; and the upper valve, of nearly all the specimens of *P. opercularis* taken off the Isle of Man, and numbering several hundreds, was covered with a Halichondrioid sponge of a rich red colour.

THE SHELL.

Scallop shells are well known at most seaside resorts. They are sold as ornaments, and have been put to various uses by the fishermen. They were used, moreover, in very early times, and it has been supposed that the flat valves were the plates and the hollow ones the drinking cups of Fingal and his heroes. Until recently, in the Isle of Man, primitive lamps were made from the deeper shells.

The majority of Lamellibranchs are equivalve and inequilateral, the right and left valves being mirror images. Pecten, however, shows a departure from this rule as the right and left valves are symmetrical, and in some species, e.g., *P. maximus*, are very unlike each other. The equilateral character is in some species disturbed by the areas near the hinge line being unequal in size. The hinge line is practically straight, and a strong internal cartilaginous ligament is situated in a deep triangular pit, under the beak of each valve (Pl. I., fig. E, *Lg.*). The characteristic shape of the valves is given by the auricular area developed on each side of the beak of the shell (Pl. I., fig. C, *Sh.a.*).

The shell of *P. maximus* is brittle and rather light for the size, which is what one would expect since a heavy shell would be detrimental in swimming. It is very inequivalve, the right valve (Pl. I., fig. C) being very convex, whilst the left (Pl. I., fig. D) is quite flat with a concave area near the umbo. In *P. opercularis* the shell is almost equivalve, both valves being convex, the left, however, is slightly more convex than the right (see Text-fig. 1). Both species have suborbicular valves, and these are marked by plications so that the outer surface has a number of ribs arising near the umbo. The ribs are not present in old specimens of *P. maximus* on the areas immediately adjoining the umbos.

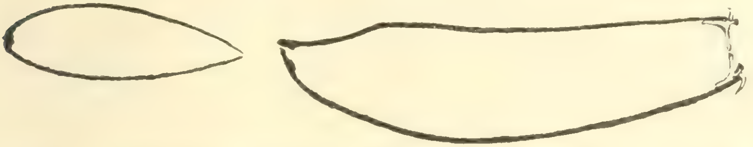

Fig. 1. Diagrammatic sections of *P. opercularis* and *P. maximus* to show shape of valves in natural position.

The number of plications appears to be constant throughout life, no new ones arising by bifurcation or interposition, and there are fewer in *P. maximus* than in *P. opercularis.* The average numbers can be obtained from the following table given by Davenport (**41**) for the shells of *P. opercularis* from three localities:—

Ribs.	Off Eddystone.		Irish Sea.		Firth of Forth.	
14	1	0·2 %	0	...	1	0·2 %
15	5	0·9 %	3	0·5 %	8	1·6 %
16	77	14·4 %	27	4·4 %	63	12·4 %
17	195	36·4 %	152	24·8 %	154	30·3 %
18	182	34·0 %	219	35·7 %	164	32·3 %
19	66	12·3 %	159	25·9 %	96	18·9 %
20	9	1·7 %	45	7·3 %	20	3·9 %
21	0	...	8	1·3 %	2	0·3 %
22	1	0·2 %	1	0·2 %	...	...
	536		614		508	

Davenport has also given the relation of the dorso-ventral diameter to the antero-posterior diameter, for 1,657 shells of *P. opercularis* from these same localities. The results show that the smallest shells are from off the Eddystone lighthouse, the largest from the Firth of Forth, and the intermediate ones from Port Erin in the Irish Sea, Also that the shells of a given dorso-ventral diameter are longest at the Eddystone and roundest at the Firth of Forth. Davenport concludes from the numbers that the ancestral Pectens had a relatively greater dorso-ventral diameter, and that modern ones are becoming longer, since the measurements indicate that change. The variations recorded with regard to most qualities and the size of shells indicate that the Eddystone and Firth of Forth forms are the extremes in a regular series, the Irish Sea specimens being intermediate. The difference in latitude means a difference in temperature, and probably also in the density of the water.

By means of the ribs and their secondary thickenings on the inner surfaces of the shell, the two valves interlock and shut closely along the ventral margin. The external ribs and grooves are sculptured with well-marked striae, radiating from the umbo. They are due to the presence of minute denticles arranged regularly in rows. There is also a prominent concentric marking as if the shell was made up of a series of lamellae. These are much more pronounced in places forming definite rings which, since they occur very regularly and in the same positions, may be considered as indicating the age of the shell. A *P. maximus* whose dorso-ventral diameter was 7·75 cm. and antero-posterior diameter 8·6 cm. had an indicated age of three and a half years.

The two valves are joined along the hinge line by a narrow external ligament, present in addition to the thick internal ligament for the opening of the shell. The former simply unites the two valves and acts as hinge. The internal ligament is triangular in section, and in appearance like dark brown indiarubber. It fits into, and is attached to, the valves in deep triangular pits. In side view this ligament is also triangular, the apex being nearest the hinge line and the base furthest from it. When the valves are closed the ligament is compressed and the free surface becomes very convex, so that the shell is only kept closed by the adductor muscle overcoming the resistance of the ligament. It will be noticed in both species that when the valves are closed there are two places, one on each side extending from the hinge line to the greatest antero-posterior diameter, where the shell edges do not meet. It is through these two prominent gaps that the water is forcibly ejected in swimming. Owing also to this feature, sea water cannot be retained in the pallial cavity when the animals are removed from their natural habitat, and hence Pecten lives but a short time compared with the Mussel and the Oyster, when exposed to the air.

In *P. maximus* the convex valve overlaps the flat valve by from one-eighth inch to one-quarter inch when they are closed. Jeffreys describes the hinge plate in *P. maximus* as toothless, but mentions certain ridges present on it. There are several tooth-like ridges both on the anterior and posterior sides of the ligamental pit, and these interlock when the valves close, fitting into grooves between similar ridges on the other hinge plate. They are not developed in *P. opercularis*. There are, further, two prominences on the right valve just at the point where the auricular areas meet the main portion of the valve (Pl. I., fig. E, *Sh.p.*). These two tuberosities rest in two depressions on the left valve when the shell is closed.

In both *P. maximus* and *P. opercularis* the auricular areas are almost equal in size, and in the former almost similar in shape, with the anterior and posterior margins inclined slightly, making an obtuse angle with the hinge line. In *P. opercularis* the posterior edges incline, making an obtuse angle as in *P. maximus*, but the anterior margins form acute angles, and that of the right valve is reflected so that the anterior left auricle overlaps it at this point. The valve is also depressed here slightly, so that a groove is formed, known as the **Byssal Notch**, and it is deeper in young forms than in the adult. Since the foot is situated so near the hinge line, it is probable that the groove is due to its presence, because the valves would otherwise have to open much wider for the protrusion of foot and byssus than is the case in the majority of Pelecypods where the foot is protruded ventrally. This would also account for the greater depth in younger forms and absence in the adult *P. maximus.* At the base of the byssal notch are three tooth-like processes, the function of which is unknown. The hinge line is almost level, but in the convex valve it rises slightly on either side of the umbo in such a way that when the shell is closed the most dorsal point is formed by the convex valve which is slightly folded over to join the upper flat valve.

The inner faces of the valves are marked by impressions indicating the attachments of the various muscles.

The Pallial Line is a scar marking the attachment of the numerous retractor muscles of the mantle edge. It is a sinuous line extending without break or indentation (owing to the absence of siphons and their retractor muscles) almost parallel to the shell margin, at a distance of about one and a half inches from it, at the ventral border (Pl. I., fig. E).

The **adductor impression** is larger on the flat upper valve than on the lower convex one. This impression is, moreover, situated nearer the ventral margin of the shell on the left valve than on the right, owing to the oblique track of the muscle fibres. The single retractor of the foot is attached to the left valve, but its impression forms part of the adductor impression.

Microscopic Structure. The observations of Jackson (**3**) on the earliest shell of *Pecten irradians* show that the "prodissoconch" (the completed first-formed shell) has a homogeneous and laminar structure with fine concentric lines of growth, no indications of the byssal notch, and is dimyarian.

The byssal notch arises in the next stage, the "dissoconch," which is sharply separated off both in structure and shape from the early shell, for a thin layer of prismatic cellular tissue was observed in the right valve extending over the whole shell. There are no ears nor plications of the shell at the early dissoconch stage, though they appear very soon after, and this is interesting because the Devonian *Pterinopecten*, an ancestral genus transitional between the Aviculidae and the Pectinidae, also shows but slight development of ears.

It is very difficult to cut sections of the adult shell owing to its brittle nature; but I have been able to examine a transverse section cut along the antero-posterior diameter of *P. opercularis* and a section along one of the ribs, that is, along the dorso-ventral diameter of *P. maximus* (right valve).

The structure of the shell is practically the same in both species, but *P. maximus* is much coarser than *P. opercularis*.

The sections differ considerably in appearance from those of *Anodon*, *Mytilus* and *Cardium*, and one cannot trace the three typical layers—periostracum, prismatic layer and nacreous layer. The first appears to have been worn away in these adult shells, though traces of it may be seen in the hollows. The calcareous structures seen probably represent both the prismatic and nacreous layers, but the crystals are not laid down as prisms, neither can two definite layers be made out. The shell is composed mainly of aragonite, the crystals of which appear to interlace and to be arranged very irregularly (Plate II. fig. 2).

In transverse sections across the ribs (fig. 2), the flattened crystals are laid down so that the structure appears to be lamellar, somewhat like the nacreous layer of other Lamellibranchs. These lamellae run practically parallel to the surface of the shell, and each rib is formed by a great thickening of this lamellate layer, the lamellae being arranged to form two crests as figured. The structure of the shell between two ribs is more irregular, and recalls the geological structure known as false bedding—the laminae lying in various planes.

While the median portion of the thickness of the shell is as described above, the external surface layer is formed of crystals which are arranged in some places perpendicularly, or nearly so, to the surface of the shell, and in this way a kind of pseudo-prismatic layer is built up, but it passes gradually into the coarser and more irregular layer below. The inner surface of the shell is also laminar in structure, the laminae being practically parallel to the surface. If the shell sections be cut through the adductor impression, a thin, delicate layer (Pl. II, fig. 2, *Sh. m.*) will be found situated between the inner lamellar layer and the adductor muscle. This is the limy-looking layer seen in surface view of the muscle impressions, which sometimes adheres to the muscle and can be pulled away with it. It is best seen in sections through a young Pecten, the shell of which has been decalcified. This layer appears to be made up of numerous fine rods placed side by side, vertical to the shell surface. In sections of older shells, the rods are not so distinct, but the layer shows very definite striae perpendicular to its surface. It is by means of this "Durchsichtige

Substanz" of List (**6**) that the adductor muscle is attached to the shell, and it is secreted by the modified mantle epithelium of the muscle area, which in the adult is very difficult to trace.

The formation of lamellibranch shells is not yet completely understood. The Intussusception theory of Méry assumed that the shell was itself a growing body. Réaumur, after Regeneration experiments, laid the foundation of the Secretion theory, according to which the shell is a secretion product of the animal. This is the theory now generally accepted. The periostracum can be traced to the actual secreting cells in the periostracal groove of the mantle edge, but difficulties have arisen in connection with the other layers, and there is no doubt that the Intussusception theory originated through the difficulty of understanding the formation of a complex shell structure from a solution or secretion partly organic and partly inorganic. In those Lamellibranchs where an outer, prismatic, layer is present, this is secreted and grows only at the mantle edge. The inner nacreous layer, or that part of the lamellar layer of the Pecten shell corresponding to it, is unlimited in growth, and is formed by the outer surface cells of the mantle.

The colour of the shell varies considerably. In *Pecten maximus* the upper valve is very generally reddish brown, the lower having a somewhat lighter yellow tint: both valves may be mottled with bands or streaks of burnt umber or yellow. *P. opercularis* varies still more, and may be almost any shade of red, pink, orange, yellow, purple or brown, with streaks and blotches. Both species are sometimes quite white, with a slight orange tint at the umbos. The inner surfaces of the valves are smooth and porcelain-like in appearance, with very frequently in *P. maximus* a broad band of a dark chocolate or burnt sienna colour between the pallial line and the margin of the shell (Pl. I., fig. F). This, however, is absent in some specimens, and does not occur in *P. opercularis*.

GENERAL ORGANISATION AND MANTLE.

It is difficult to kill and preserve the specimens without a considerable amount of contraction and distortion taking place. Crystals of menthol dropped into the sea water in a small dish containing a specimen of *P. opercularis* produce the best results with the least retraction of the tentacles and mantle. For *P. maximus*, the mixture of Lo Bianco, spirit glycerine and sea water, floated gradually over the water in the vessel containing the specimens, gives very good results. When narcotised sufficiently in this way, the animal should be placed in 5 per cent. formalin, and may remain in this until required, the muscle, however, becoming somewhat hard.

The animal should be removed entirely from the shell by separating the mantle lobes carefully with the handle of a scalpel and cutting the attached portions of the adductor muscle, and can then be pinned down and examined under water.

For serial sections, the smallest specimens obtainable should be dropped into Perenyi's fluid or Pikrosulphuric, and fixed according to the usual directions. These fluids dissolve also the calcareous part of the valves so that the specimens are ready for embedding after dehydration.

When removed from the shell it will be seen that the viscera and body proper are hidden between two folds of the body wall, the mantle or pallial lobes, which are almost of the same shape and size as the valves of the shell to which they were attached by muscles (Pl. II., fig. 1, *M.n.*). These lobes enclose the pallial cavity, in which lie the gills (fig. 1, *Br. d.*, *Br. a.*) and the lower part of the visceral mass.

The Mantle consists of two thin lobes, folds of the tegumentary layer of the body, with epithelium covering both external and internal surfaces (fig. 4, *E. Mn.*), and but little connective tissue and muscle fibres except at the free margin which is much thickened and muscular. The mantle epithelium is the outermost layer of the body, the shell being a secretion on its surface. The outer layer which lines the shell extends from the hinge line (where it becomes continuous with the same layer on the other side) to the ventral edge of the mantle, as a continuous sheet. It is to be found, though modified, between the adductor muscle and the shell, lying between the muscle fibres proper and the peculiar calcified layer (fig. 2, *Sh. m.*) which is found on the internal surface of the shell at the muscle impressions.

The inner layer is reflected inwards at several points to be continued over the visceral mass. For example, it passes over the adductor muscle and on to the gonad; dorso-posteriorly it runs across from one mantle fold to the other just above the pericardium (fig. 1, *Per.*), partly forming its roof and supporting the posterior pallial artery (fig. 14, *A. p. p.*) which can be easily seen running up towards the hinge line. The two layers of the mantle do not pass over the sides of the digestive gland (fig. 1, *Dg.*). The inner one becomes closely apposed to it, anteriorly and posteriorly, forming the body wall here, whilst the outer epithelial layer alone clothes the sides of the gland.

Dorsally the right and left mantle folds are continuous along the full length of the hinge line, as has already been pointed out, but the level of this is broken about the middle of its length where there is a rectangular depression of the mantle (fig. 1, *Lg. P.*). Into this depression the ligament dips, lying transversely across it. There are no fusions of the mantle edge to form separate inhalent and exhalent apertures, and consequently there are no siphons. The inhalent and exhalent currents are, however, confined to special regions, so that physiologically the fusions are not needed for the separation of the currents. By scattering some carmine into water in which a Pecten is living, the particles of colour can be seen entering all round the shell between the two folds of the mantle, except for an area extending from the posterior end of the hinge line for a short distance forward. Here there is a very definite exhalent current sometimes accelerated by the animal closing the shell suddenly and forcing the water out at this point only, to eject the faeces.

The free margin of the mantle lobes is much thickened and presents three typical folds (fig. 4). The outer one, the shell fold (fig. 4. *Sh. F.*), is small and bears long tentacles. The median one, the Ophthalmic fold (fig. 4, *Op. F.*), is not so distinct and also bears tentacles and the eyes which form conspicuous objects when the animal is alive. The most internal fold is much the largest and is turned inwards to form a flap, known as the "**velum**" (figs. 1 and 4, *V.*). It is usually pigmented either continuously or at regular intervals. List (**6**) has shown that the storage of pigment in the mantle cells is directly influenced by light, and that removal of a piece of the shell causes a deepening in colour of the tissue exposed, due to formation of pigment. This curtain-like velum becomes reduced in size as it approaches the base of the angle forming the ears, and it is this inner portion of the mantle on both sides that fuses as mentioned above. The outer folds remain free, with their eyes and tentacles, until the dorsal margin is reached. The tentacles (fig. 1, *Tn.*) are long, very extensible and active on the outer fold, while those arising from the velum (fig. 1, *Tn. v.*) are short and move but little. When fixed they appear papillose, but this is due probably to the great difficulty in fixing them without contraction and folding of the surface tissue.

The outer tentacles are roughly separable into two groups, a series of short tentacles, mainly one row deep, lying next to the shell, and longer ones capable of much extension and contraction inserted in one or two irregular rows. The former are unpigmented in both valves, and lie, when the shell is opened, curved back over the shell. The others of the upper or left valve have a streak of pigment on their upper sides, and a similar, but less intense, streak is present to the same side of these tentacles on the lower valve.

Further details in regard to the eyes will be given in the chapter on those organs.

When the valves of the shell are separated the two vela hang at right angles to the plane of the valves, just touching, like two curtains. The small tentacles lie across one another, and form a rude grating. The velum, as we have seen above, is of great importance in connection with locomotion. It has been pointed out in considering the muscle impressions on the shell that the fibres of the adductor cross the body obliquely (figs. 46, 47, *A. s.*), the result is that the right mantle lobe has a free portion of much greater area than the left.

HISTOLOGICAL STRUCTURE OF THE MANTLE.—Over the whole surface of the mantle there is a single layer of cubical or columnar epithelial cells, forming the epidermis. These cells become much more distinctly columnar towards the free edge of the mantle, and are in many places crowded with pigment granules of a dark brown colour, particularly on the velum. A very delicate cuticle is also present. In the young Pecten the epidermal cells near the margin of the mantle and on its outer surface are very long compared with those of the epidermis elsewhere, and are evidently active secreting cells of the shell substance. In adult specimens this great difference is not seen. The columnar cells on the free margin of the mantle lobes, especially on the eye stalks (fig. 35), have a very peculiar appearance, due either to delicate connecting bridges like the "prickle cells" or to the walls having processes which interlock; most probably the former. Lying amongst these epithelial cells are numerous sense cells ("pinselzellen"), to be described later in the chapter on the sense organs.

Underlying the epidermis, there is at the margin of the mantle lobes (fig. 4) a substantial connective tissue, consisting of delicate fibres with few scattered nuclei. There are numerous blood spaces in this layer, and the circumpallial artery (fig. 4, *A. c.*) and the circumpallial nerve (fig. 4, *N. c.*) pass through it, in close proximity, the blood vessel being situated on the shell side of the nerve. Passing inwards, away from the margins, the mantle lobes become extremely thin, the structure being more and more trabeculated until, after passing the line of attachment of the pallial muscles, there is practically nothing between the epidermal layer of cells but bridges of fibrous tissue, large spaces being left in which are to be seen numerous blood corpuscles with large nuclei.

Ramifying in the connective tissue before mentioned, at the margin of the mantle lobes, are the pallial muscles (figs. 1, 3, 4, *P. M. r.*, *P. M. c.*, *P. M.*).

The pallial musculature of Pecten is both important and complex, and the edges of the mantle are very well supplied, owing to the energetic part played by the velum in the act of swimming and the necessity of withdrawal and protrusion of the edge with its numerous sensory structures. It has both radial (fig. 3, *P. M. r.*) and what may be termed concentric muscles; the latter extend round the margin of the mantle parallel to its free edge, and are well developed in the velum (fig. 4, *V. M. c.*), which has a very compact muscular structure.

The radial muscles are the most obvious when examining the mantle, for it is these which attach the mantle edges to the shell and retract them when the valves close.

The line of attachment on the shell has been previously seen to be a continuous line extending almost parallel to the shell margin and at some distance from it, furthest at the ventral edge and approaching it anteriorly and posteriorly. These pallial muscles proper arise, where attached to the shell, as slightly separated bundles of fibres, as if, in fact, a bundle had the end frayed out slightly. These separated fibres almost immediately come together again to form a conspicuous large fibre which radiates out to the margin and breaks up into very numerous finer bundles, which interlace and become crowded together as they reach their termination at the base of the velum.

Between the outer pallial fold bearing the tentacles and the median one bearing tentacles and the eyes, there is a deep groove, known as the Periostracal groove (figs. 4, 6, *P. gr.*), and in sections the periostracum can be seen arising from the base of the groove through the coalescence of several short fibres from the secreting cells. From here it is continued out, and passes over the edge of the shell to its outer surface.

At the bottom of the groove lying along each side there is a ridge formed by much elongated epidermal cells, together with a fold of this layer with a slight support of the underlying connective tissue (fig. 6, *P. gr.*). The periostracum (fig. 6, *P.*) emerges from between the two ridges, the cells of which differ from those of the surrounding area. They are glandular, and have deeply staining contents.

The cells lining the side of the groove nearest to the eye bear long cilia, and resemble very closely the sense cells which will be described later. Very short cilia are present on the epidermal cells of the outer margin of the shell fold. The cilia are much better developed on the tip of the ophthalmic fold, which bounds the periostracal groove on the inner side. The epithelium of the inner surface of the mantle lobes is also ciliated.

Insinuated between the ordinary epidermal cells on the outer surface of the mantle, near the margin are to be seen peculiar cells (fig. 5, *Eos.*) which contain numerous large rounded granules that stain bright red with eosin or a compound stain containing eosin, such as Mann's methyl blue-eosin. In some places these cells seem to be forcing their way to the surface, and in one or two cases the actual dehiscence of the cell and its contents is observed. They are similar to the cells described as eosinophilous cells by Herdman and Boyce in the Oyster (**42**), and in all probability are wandering cells exercising an excretory function. The tentacles of the shell and ophthalmic folds have a similar layer of columnar epithelial cells to those found on the margin of the mantle, but sense cells are particularly numerous at their tips. The connective tissue of the tentacles (containing muscle fibres running longitudinally from the base to the tip) is divided into segments by transverse muscle fibres, which radiate out from the core of the tentacles to the periphery. A branch from the circumpallial nerve innervates each tentacle, passing up the centre and giving off branches to the sense cells.

If the mantle lobe of one side, preferably the right (where the adductor muscle is attached much nearer to the hinge line), be removed, the general topography of the viscera can be easily made out. The various organs thus exposed are shown in Pl. II, fig. 1. The single adductor muscle occupies a fairly central position (fig. 1, *A. u.*, *A. s.*), and serves as the support for the greater part of the animal which surrounds it. Against the hinge line is the deeply pigmented, green-black looking gland, the so-called liver, which will be referred to as the digestive gland (fig. 1, *Dg.*). The gills (*Br. a.*, *Br. d.*) are very conspicuous structures, lying between the visceral mass and the mantle and attached to the latter on the right side, so that if the mantle were cut away close to the adductor the gills on this side would also be removed. They consist of a long series of orange coloured filaments suspended from a basal lamina.

The body proper may be divided into:—(1) Viscero-pedal mass, (2) the pericardium and rectum, and (3) the renal organs.

The viscero-pedal mass consists of (*a*) the Digestive Gland which is situated at the posterior and dorsal extremity and encloses the stomach, and (*b*) a long, flattened, tongue-shaped reproductive portion, of a brown colour over the whole area, or if the gonads are ripe—white for part of its length (the testis), and pink or brilliant scarlet for the rest (the ovary). There is no distinct division between the digestive gland and this latter portion of the viscera, but just where they are contiguous the rudimentary foot (fig. 1, *F.*) is situated. It is roughly cylindrical in shape: the distal portion, however is sucker-like, with a deep cavity. The foot, it will be seen, appears as an appendage quite distinct from the rest of the visceral mass, and contains no extensions of the reproductive organs.

The pericardium (fig. 1, *Per.*) is situated posterior to the digestive gland. The rectum (fig. *Al. c. 5*) passes through the ventricle of the heart, which is enclosed by the pericardium, and is continued over the adductor muscle, to which it is attached, bending to one side of the median line and eventually terminating in a lipped anus.

The aperture of the mouth is placed not far above the foot on the anterior surface of the digestive gland between the two very conspicuous dendritic lips, pigmented with an orange colour (fig. 1, *L. p.*).

At each side where the gills terminate dorsally are two flaps, also pigmented with a yellowish brown colour. These are the Labial Palps (fig. 1, *L. p. e.*); they become continuous dorsally with the lips.

The renal organs (fig. 1, *R. o.*) are situated on each side of the reproductive portion of the viscera between it and the gills, and the external opening at their ventral end serves both as renal and reproductive aperture (fig. 1, *Ro. rp.*).

The positions of these various organs in relation to the shell are not the same as those in the Dimyaria. Thus the pericardium is posterior, the digestive gland ("liver") is dorsal and the foot and visceral mass are situated anteriorly, the hinge line being considered as dorsal.

Owing to this, some authors have regarded the hinge line as dorso-anterior, and the antero-posterior diameter as represented by a line drawn from the front corner of the hinge line to the point where the rectum ends. The position of the organs is regarded as due to an increase in size of the posterior adductor after the disappearance of the anterior adductor, together with a movement of the muscle to a more central position. A shortening of the length of the body with a closer attachment of the viscera to the muscle (which plays a prominent part as a support, and rotates slightly), would bring about the conditions observed. Throughout this Memoir, however, the hinge-line has been taken as marking the dorsal edge of the body.

THE MUSCULATURE.

Pecten belongs to the Monomyaria, since it possesses only a single adductor muscle. The possession of one adductor muscle by certain lamellibranchs does not indicate genetic relationship, and species which are Isomyarian, Anisomyarian and Monomyarian may all be found in a single family. In addition to the adductor there are present, the orbicular retractor muscle of the mantle (pallial muscles), a single retractor muscle of the foot on the left side, the intrinsic muscles of the foot and visceral mass, and the heart or cardiac muscles.

The Adductor Muscle of the Shell (fig. 1, *A. s.* and *A. u.* and fig. 47) is the posterior one of those forms with two adductors present. In the early stages, after the free swimming larva, we have first a protomonomyarian stage when the anterior adductor is formed and is alone present. The next is a dimyarian stage when the posterior adductor is present in addition to the anterior. These two stages are quickly passed through, the anterior adductor disappears and the posterior increases in size and takes up a more central position. This may be called the deutomonomyarian stage. The muscle stretches obliquely across the body from one valve to the other. The attachment to the shell is more dorsal on the right valve, and, owing to the fact that the fibres cross obliquely, the various organs of the body that surround the muscle are also asymmetrical, and the right mantle lobe is of much larger extent below the adductor than the left.

There is an obvious separation of the single adductor into two parts (fig. 1, *A. u.*, *A. s.*) one of which is of different structure from the other. In the fresh or living animal these two regions are easily distinguished by their different appearance, but they are quite distinct even in preserved specimens.

The greater part of the muscle (*Add. s.*) has a colourless, semi-translucent appearance, and this part is cylindrical in section near the right valve, but elongates and increases in area as it approaches the left valve, where the muscle impression is slightly larger. Lying against the posterior surface of this main portion, but clothed by the same connective tissue sheath that passes round the two parts and binds them together, is a narrow bundle (*Add. u.*), crescent shape in section and made up of white, more opaque looking fibres. Coutance (**13**) and Thoring showed that the larger part serves only for the *rapid* spasmodic closing of the shell, while the small portion serves for slower but more forcible and sustained activity. If one valve is taken away, which means that the attachments of the adductor are cut through, the small white portion falls into a state of permanent contraction ("tonus") and thus in fixed preparations this portion of the muscle is generally much more strongly contracted, and, therefore, shorter than the larger part of the muscle.

The other part contracts and relaxes rapidly if stimulated. It is obvious that this development is correlated with the function of swimming, and that the clapping of the valves of the shell is due to the large translucent portion of the adductor, whereas the more permanent closing of the shell is due to the much smaller part. *P.*

maximus can resist a considerable pull for a short time, 4,000 grams are not sufficient to pull the valves apart unless acting for some time, when, as is the case with other lamellibranchs, a much less weight suffices to open them, in fact, as has been shown, starfishes are able to open oysters by a sustained pull. Corresponding to these differences in appearance and function there are differences in the histology of the two regions. The fibres of the large, rapidly contracting part, when seen in sections, show a very obvious striation, the smaller portion of the muscle consists of smooth fibres. This relation between the cross striation of muscle fibres and rapidity of movement is of general occurrence (**13** & **15**). The striated fibres are very much flattened so that they can be seen either in surface or in edge view (fig. 30, *b*. and *a*.).

If small portions are fixed in osmic or Flemming and stained with iron haematoxylin it is quite obvious that the striping consists of distinct transverse bands: there is no possibility of its being only an appearance due to fibrillae being thrown into spirals when in a contracted state.

The dark bands are three or four times as long as the light, almost unstained, portions. Moreover, the fibres have a series of constrictions which correspond in position with the light stripe; this can be seen extremely well if a fibre is observed in edge view, so that the dark portions correspond to the swellings and the light stripes to constrictions.

The difference in intensity of the stain taken up by the two parts, however, is so great that it would be difficult to affirm that the dark stripes are due to a greater thickness of stained protoplasm, though it is possible that this may be the case (see **14**).

The nuclei of the fibres are not frequent in occurrence, and are pushed rather to one side of the fibre and elongated.

The muscle is well supplied with blood brought by the adductor artery, and the whole substance of the muscle is permeated with lacunar spaces in which blood corpuscles can be seen. The adductor contains also a very large quantity of glycogen, which can be easily extracted with water and the characteristic tests applied to the solution. The means of attachment of the adductor muscles to the valves can be best observed in complete sections through a very small Pecten, the shell of which has been decalcified. The union of the muscle fibres with the shell is carried out by a special attachment epithelium, the cells of which fuse with the muscle fibres so that their original epithelial nature is difficult to trace; and this tissue element appears to secrete the specialised layer of shell at the adductor impressions (fig. 2, *Sh. m.*).

The Radial Pallial Muscles (figs. 1, 3 and 4, *Pall. M. r.*) are confined to the edges of the mantle lobes, and their attachments and course as seen in surface view, have been described above. At the point where they are attached to the shell, the epithelial cells can be seen extending between them and the shell, but slightly modified. From this point, where the fibres are inserted very obliquely, they pass outwards, towards the margin of the mantle lobes, drawing gradually nearer to the inner surface of the mantle, until most of them terminate at the base of the velum. In certain sections taken through the mantle of *P. opercularis*, some of these fibres appear to be striated, the stripes being apparently transverse. The striping, however, is not nearly so obvious nor so regular as that of the adductor muscle, and, moreover, it cannot be seen in all sections, even those cut very near to each other and treated with the same fixative and stains. The question arises, therefore, whether this cross striation seen in some of the radial pallial muscles is not due to the fibrils being thrown into folds by contraction, producing an apparent striation only. Transverse striation has also been observed in *Pecten opercularis*, on the ctenidial muscles (fig. 45, *Br. m.*), the appearance here being exactly as in the mantle. Both cases are probably due to contraction.

The Circular Muscles run parallel to the margin of the mantle and are very well developed in the Velum (fig. 4. *V. M. c.*), which is made up almost wholly of these muscle fibres. When Pecten closes its valves rapidly, whilst swimming, the water between the valves must endeavour to escape at the ventral margin by forcing the two vela apart. One can see, then, the use of this development of circular muscles, because if the vela are kept in a rigid condition by their action, the water will be compelled to pass out at each side dorsally, near the hinge line, as previously described. These circular muscles are inserted into the shell in conspicuous bundles anteriorly and posteriorly (fig. 3, *V. M. a.*) at the same level as the fusion of the mantle lobes.

The Retractor Muscle of the foot is the posterior retractor of the left side, and is the sole representative of the four retractor muscles which attach the foot and contained viscera to the shell in the majority of lamellibranchs. In monomyarian forms, the two anterior retractors are usually absent, but Pecten has gone further, and, moreover, the single retractor which is obvious in *P. opercularis* has become even more vestigial in *P. maximus*.

In both species the attachment to the shell is in the same position, along the dorsal margin of the adductor muscle, near the junction of its two parts, and the retractor impression on the shell cannot be distinguished from that of the adductor.

The fibres are inserted at a considerable angle, and from the shell, they pass first as a flat band and then, becoming circular in section, across the dorsal surface of the adductor, directly towards the base of the foot. This brings the Retractor under the pericardium and the digestive gland until it reaches the visceral mass, through which it plunges, just at the junction of the digestive gland and reproductive organ, lying enclosed in a fairly definite blood space. Transverse sections through the muscle close to the base of the foot show (fig. 47, *B. g.*) that the muscle has taken a tube-like form, enclosing the byssus gland. The muscle fibres pass around the gland, which has the form of compressed pouches separated by lamellae of connective tissue, and ultimately they become lost in the tissue of the foot.

The Intrinsic Muscles of the foot make up the bulk of the tissue in this part of the body (fig. 8). They run chiefly in two directions. There is a definite layer of circular muscle fibres underlying the surface and extending all round the foot, more internal still is a series of longitudinal muscles running along the axis of the foot. In addition there are many fibres diverging radially from the centre, and also scattered fibres passing in various directions.

Other intrinsic muscles are to be found in the visceral mass in the reproductive region. There is a layer of transverse muscles passing round in the connective tissue sheath which encloses the visceral mass, and connected with this sheath are scattered muscle bundles running across from one side to the other and serving to strengthen and form a support for the alveoli of the gonad.

The Ctenidial Muscles (fig. 45, *Br. m.*, *Br. m.'*, *Br. m.''*) are arranged as follows:—There is first a layer of muscle fibres (fig. 45, *Br. m.'*) underlying the epithelium but separated from it by connective tissue: these run, like the gill filaments, at right angles to the axis. More remote from the surface there is a somewhat scattered layer of fibres running in the direction of the gill axis. Internal to these again and separated from them by more connective tissue is another layer of fibres running in the same direction as the first described (fig. 45, *Br. m.''*).

In addition to the above there are two very important compact bundles (fig. 45, *Br. m.*) which run longitudinally along the gill axis. They are situated at the sides of the axis just above the point at which the various filaments separate from one another (*Br. m.*). In certain sections of *P. opercularis* these muscles have shown a very similar striation to that of the pallial muscles. These last muscles serve for contraction of the gills.

The Cardiac Muscles.—The auricles and still more the ventricle are well supplied with muscle fibres. They extend around the heart, lying just internal to the wall and passing in various directions from the walls across the cavity dividing it up, so that it has almost the appearance of a sponge. These muscles are described with the heart. It is interesting to note here, however, that in the specimens fixed and sectioned, no traces of definite striation were found on these fibres, except in one case, resembling that of the radial, pallial and ctenidial muscles.

FOOT.

The Foot is a very small organ situated high up on the anterior surface of the visceral mass (fig. 1, *F.*), arising from the surface of the gonad close to the mouth. In shape, it is roughly cylindrical with a sucker-like termination (fig. 7, *F. s.*). This free end of the foot which is almost bifid has a very deep cavity, the dorsal boundary wall of which extends further distally than the ventral, which is notched.

Two sides of the foot can be distinguished, the dorsal and the ventral, the latter has a groove running longitudinally along its surface for about half of its length (fig. 7, *P. b.*). This is the byssal groove and communicates with the byssal gland.

The deep cavity of the end of the foot is continued down the centre until it almost reaches, if it does not communicate with, the cavity of the byssal gland and groove. The foot is very contractile, and in fixed specimens is usually much contracted and wrinkled; it does not contain any extensions of the viscera, and the greater part of its bulk is composed of muscle fibres running in various directions in a groundwork of connective tissue. It is bounded by the usual epidermal layer of epithelial cells, which are columnar, the depth being about three times the width. These cells are ciliated over the whole outer surface, and even extend into the deep cavity of the end of the foot. These ciliated cells are very fine objects for showing the striated cell margin seen in ciliated epithelium.

The epidermis lining the cavity of the foot differs, however, from that on the outer surfaces in that the epithelial cells are compressed in the middle part of their length, so that they are somewhat hour-glass shaped and have interposed between them many mucous glands (fig. 10, *Mu. g.*). In these, nuclei are indistinguishable, but from the size and shape it is extremely probable that these glands are unicellular. In places, in sections, the mucus can be seen emerging from between the epithelial cells, and if the foot of living specimens is examined the cavity will be almost always found full of mucus. In addition to these there is another layer of mucous glands (fig. 10, *Mu. g. c.*) situated more internally but not far from the epidermal layer above described. These appear to be similar to the mucus-secreting glands described by Johnstone (**4**) as occurring on the foot of Cardium. The glands consist of groups of cells aggregated together; sometimes where a group is more distinct it can be seen to consist of about 5-8 cells forming a kind of bulb. From this clump of cells a long stalk arises which passes to the surface and insinuates itself between the epithelial cells; it may divide into two or more branches just below the epidermal layer. The stalk is non-tubular, and the contours of the cells composing it cannot be distinguished. The ground substance of the cells is finely granular, and stains a peculiar grey-blue tint with methyl-blue-eosin.

Under the epidermis there is a layer of connective tissue comparatively free from muscle fibres, and the rest of the foot is made up, as previously mentioned, of connective tissue and muscles. Large blood spaces are to be found scattered through the connective tissue and connected at the base of the foot with the pedal artery which enters it on the dorsal side; the blood lacunae are connected with others which pass over the visceral mass to the dorsal extremity of the renal organ.

There is also a very abundant nerve supply; the pedal ganglia, as will be seen later, are not situated in the foot. Two pedal nerves pass from these, and after entering the foot break up into smaller bundles (fig. 8, *N. p.*), which ramify amidst the connective tissue and innervate the muscles.

The Byssal groove which is seen on the ventral surface of the foot, is a deep groove lined by ciliated cells, and extending almost half way across the diameter of the foot. In *Pecten opercularis* the foot is twisted so that the surface with the byssal groove faces the right valve, and it will be remembered that it is the right valve of the shell that has the indentation known as the byssal notch. Though there are no traces of the byssus in the adult *P. maximus,* the byssus gland is very well developed. It is situated very deeply in the tissue, in fact practically outside the foot, in the midst of the retractor muscle. If a series of transverse sections is followed from the byssus groove region of the foot to the retractor muscle, the following sequence will be observed: The byssal groove is rather wider at the bottom, and this cavity runs in towards the byssus gland. In sections taken below the byssus groove the sides of the groove have coalesced and the cavity alone is present. As we pass further in, the dorsal wall of the cavity becomes ridged by longitudinal projections, which gradually meet the ventral wall, so that ultimately the original cavity is divided up into compartments by parallel partitions running across from the dorsal to the ventral wall (fig. 47, *B. g.*, and fig. 9). These compartments are deep and wide, but very narrow. Sections showing this structure pass through the retractor muscle alone, and are therefore posterior to the actual foot itself.

The partitions are composed of connective tissue in which are to be found many muscle fibres, and are bounded by a layer of epithelial cells almost cubical in shape, and of course continuous with those of the byssal gland. They are well provided with cilia. The compartments terminate blindly, and at the same time become reduced in width; but at their blind ends, the cells (fig. 9 *B. g. c.*) are rather larger than the other epithelial cells and contain practically no contents. A structureless body, presumably the nucleus, is present in each, but it stains differently from the other nuclei and is probably in some exceptional condition. In addition to these features the cells have long cilia-like processes which are almost as long as the cells themselves, and these meet in the centre of the space. In the Pearl Oyster (*Margaritifera vulgaris*) (**2**), where there is a well-developed byssus, the same threads are present in connection with the secreting cells of the byssus, and they pass into the horny mass which appears to have been secreted round them. No byssus is present in *P. maximus*, but these cells are presumably the gland cells, and the peculiar cilia-like processes are identical with those forming the root of the byssus in the Pearl Oyster.

With regard to the functions of the foot, which seems so rudimentary in the adult, we have already seen that in the early life history it functions as a locomotive organ, while later on it becomes an organ for attaching the byssus threads to a foreign body. In the adult it seems from observations to perform neither of these functions, though in the case of *P. opercularis*, the time during which byssal threads are formed is probably long, and in *P. varius* the byssus is spun and fixed even in the adult stages.

That the foot can be moved about and extended is easily seen when watching the living animal, and in one case it was observed that this extension brought the apex of the foot outside the valves altogether. It probably is of use, therefore, for freeing the palps and gills of foreign particles, as the foot of the pearl oyster has been observed to do. The cavity at the apex always contains a quantity of mucus, and we have already seen how well the foot is provided with glands. This mucus may be secreted for the purpose of entangling the food particles that are wafted to the mouth, by the gills and palps.

THE GILLS.

The Gills or Ctenidia (Pl. II., fig. 1) are conspicuous in the pallial cavity when the valves are opened, and extend like orange tinted curtains on each side of the visceral mass, with their free edges reaching from the labial palps to a point opposite the end of the Rectum. At first sight there appear to be two gills on each side of the body, but the morphological identity of the lamellibranch gills with the ctenidia of other mollusca is now fully established, and there is but one ctenidium on each side. These two apparent gills are two plates (double for the greater part of their area), formed by a series of filaments loosely attached to one another. The two opposite and innermost lamellae meet, fuse, and become continuous with a supporting ridge at their proximal edges, but their lower or distal edges are reflected so that in section each gill has the appearance of a **W**, the two outside limbs being the reflected portions, and only two-thirds the height of the middle ones by which the ctenidium is attached to the body. The transverse section is diagrammatically represented in fig. 20. Each of these double plates is known as a demibranch so that there are two demibranchs on each side, an inner and an outer, which together make up a ctenidium.

Each Ctenidium consists of a supporting axis or ridge (fig. 20, *Br. ax.*) from which depend two regular series of long delicate filaments. These two series form the two direct or descending lamellae, this part of the filaments being known as the descending filament (fig. 20, *Br. d.*). The lower ends of the filaments are reflected as previously seen (fig. 20), on the outer side of the external demibranch and the inner side of the internal demibranch, and the ascending or reflected portions of the filaments make up the reflected or ascending lamellae, corresponding to the outer limbs of the **W** in the diagram.

The direct and reflected lamellae of one demibranch are quite continuous, and the reflection is simply a device for increasing the area of the gills without occupying an awkwardly large space. The reflected lamella (fig. 20, *Br. a.*) does not reach the axis of the ctenidium, neither is it connected by cilia or other means with the mantle or with the ctenidium of the opposite side. Nor is there any connection between the two demibranchs of one side except at the axis from which they arise.

The **Ctenidial Axis** (fig. 20 and 45, *Br. ax.*) is a plate-like ridge of connective tissue of considerable depth, depending from the body wall. On the right side where the adductor is inserted nearer to the hinge line than on the left, the axis arises not far from the labial palps and is attached to the adductor muscle. It continues ventrally, gradually increasing in depth, until it passes the point where the afferent branchial vessel from the renal organ enters it, and just where the pallial nerves from the visceral ganglion enter the mantle. Here its course is diverted and the ctenidial axis leaves the adductor and is suspended from the mantle lobe. It terminates at a point almost level with the end of the rectum, but its posterior extremity does not diminish in depth, the filament-bearing margin continues almost parallel to the attached edge, and the posterior extremity has a slightly bifurcated appearance as shown in fig. 1. On the left side the ctenidial axis is attached to the adductor muscle along its whole length, and does not extend quite so far back as that of the right side.

The axis is made up almost entirely of connective tissue, with a good supply of muscle fibres (fig. 45). It is bounded by the usual epidermis formed of a single layer of epithelial cells, amongst which sense cells occur frequently on the sides.

Under the epithelium the connective tissue is more compact and dense than elsewhere with the series of muscle fibres (fig. 45, *Br. m.'*, *Br. m."*) which have been already described. Vascular spaces are of frequent occurrence in the connective tissue.

Near the margin to which the gill filaments are attached, and running in the same direction as the ctenidial axis, are the branchial nerve (fig. 45, *N. Br.*) the afferent branchial vessel and the efferent branchial vessel occurring in the order named (fig. 45, *Br. aff.*, *Br. eff.*), the nerve being nearest to the body and the efferent branchial vessel to the gill filaments. The two blood vessels are very close together, and are only separated by a narrow bridge of connective tissue. From the two corners of the afferent branchial vessel nearest to the gill filaments (it is almost rectangular in section) branches are given off which pass between the wall of the efferent vessel and the surface, and open into expansions on certain of the filaments.

The filaments which make up the lamellae are hollow outgrowths from the axis, and arise as simple, straight processes, becoming reflected later. Jackson found in *P. irradians* that the young forms examined had comparatively a much shorter reflected portion than the adults.

The gills of Pecten are amongst the best examples known of the *plicate type*, that is, the filaments, instead of being arranged in a flat uniform series, are so placed that the lamellae are thrown into a series of vertical folds or plicae (fig. 22, and Text-fig. 2). This plication is most obvious near the ctenidial axis where the folds are so deep that their surfaces are situated at right angles to the plane of the axis. The plication is least near the free ventral edge of the lamellae. Further, the filaments are not uniform in size or structure, those occupying the bottom of the furrows between two successive plicae being larger and known as *Principal filaments* (figs. 21, 22, *Fil. p.*). Owing to the presence of two forms of filaments the gills are known as *Heterorhabdic gills.* Principal filaments are only developed in plicate gills, and always in connection with interlamellar septa, which are organic sheets of membrane connecting the ascending and descending portions of these filaments (fig. 22, *Br. g. l.*). In very young specimens the principal filaments and interlamellar septa are not developed, both being secondary differentiations.

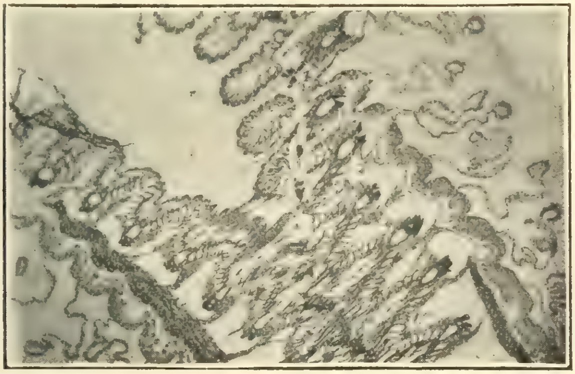

FIG. 2. Section through base of gill filaments. × 50.

The adjacent ordinary and principal filaments are connected in *P. maximus* and *P. opercularis* by stiff cilia only, arranged in patches known as ciliated discs. The cilia of two opposite discs interlock just as two brushes can be made to do. There are no organic interfilamentar junctions, and so the various filaments can be separated easily in the living animal. Organic interfilamentar junctions occur in *P. tenuicostatus* (**1**), which makes with *Avicula argentea* and *Margaritifera vulgaris* (**9**) a third exceptional member of the Eleutherorhabda.

The histology of the gills has been worked out from serial sections cut chiefly parallel to the ctenidial axis, that is transversely through the filaments, but in addition sections have been cut parallel to the filaments in two directions.

Perennyi, or Mann's Fluid, can be used for fixing the gills, and then Methyl-blue-eosin differentiates the chitinous framework well, staining it blue, the cytoplasm purple and the cilia bright red. The principal filaments should be dissected out, stained, cleared and mounted in Canada Balsam in order to make out the various parts.

The filaments are tubes bounded by a very delicate epithelial wall, the cells of which differ in shape and size at various points.

The ordinary filaments (fig. 23, *Fil. o.*) have deeper cells round the margin further away from the interlamellar space, and these cells are deepest in three places forming longitudinal ridges, the cells of which bear cilia. Thus in transverse sections of the filaments there will be seen three sets of cilia on the filament, one down the frontal surface—the frontal cilia (fig. 23, *C. fr.*)—and one on each side of the filament—the lateral cilia (fig. 23, *C. l.*), a narrow space separates the frontal from the lateral cilia. This disposition of cilia is characteristic of most of the Lamellibranchiata. These cilia, unlike those of the ciliated discs, are, in life, in constant action producing the currents of water on which the animal depends for its food supply and oxygen.

The ciliated discs are patches of elongated cells situated on the sides of the filaments near the interlamellar margin, forming little cushions, and these are found at regular intervals down each filament, those of adjacent filaments being, as a rule at the same level. The walls of the filaments are thus brought much closer together, and the narrow space is occupied by the stiff interlocking cilia which these cells bear.

The upper ends of the ascending portions of the filaments (fig. 21, *Br. a.'*) are almost entirely large, ciliated discs, for they have no organic connection, but are held somewhat firmly in position by the great development of interlocking cilia.

Each of the filaments, ordinary and principal, is strengthened by a skeletal support formed of chitin. Thus the skeleton of the gill can be prepared by acting on the soft tissue with warm caustic potash.

In the ordinary filaments this skeleton is a simple tube lining the inner surface of the epithelium (fig 23), the chitin is thinnest on the margins facing the pallial and interlamellar cavities respectively, and thickest on the sides. At one place on each side, nearer the interlamellar margin than the frontal margin, the chitin tube is much thicker, and a septum arises here and crosses the filament dividing the tube into two parts.

This septum, known as the Intrafilamentar Septum (fig. 23, *Fil. sep.*), is generally spoken of as being chitinous. In most of my sections where it is seen distinctly, it appears to stain quite differently from the chitinous skeleton, appearing almost as if it were cellular, and nuclei have been seen in it which were not adhering blood corpuscles.

There has been much discussion regarding the presence of a continuous layer of endothelial cells lining the tube of the filaments on the inner side of the chitinous skeleton, and the point does not seem to be easily settled. Ridewood (**12**) was not able to obtain any conclusive evidence, and Pelseneer (**7**) and Janssens (**10**) state that the layer does not exist, while Kellogg (**5**), Menegaux (**17**) and Sluiter affirm that it is present. It is interesting to note that Kellogg (**5**) states that in *Pecten irradians* the intrafilamentar septum is endothelium and not chitin, and in many cases in *P. maximus* the same appearance is seen. I should not, however, care to affirm that an endothelial lining exists.

With regard to the function of the intrafilamentar septum, a very plausible suggestion has been made that when the ascending filaments are not in organic connection, the blood circulating in them must come back again to the gill axis, and the septum keeps the two currents distinct, whereas when the filaments are united there is only one current running one way or the other in each filament.

Ridewood (**12**) has shown that the septum occurs, however, both in forms with the ascending filaments in organic connection and in those without.

Further, as will be shown later, the ordinary filaments only communicate with the efferent vessel, and I am inclined to believe, therefore, that what circulation there is in the ordinary filaments is simply a current down the filaments which becomes slower, stops, and then returns by the same channel as observed by Kellogg in *Arca*. It is much more likely, as Drew suggests, that the septum is a brace to keep the filament from swelling laterally owing to the pressure of the blood, and in this way becoming circular and obstructing the flow of water between the filaments.

At the interlamellar margin of the filaments, and lying between the chitin skeleton and the epithelium, is a delicate nerve (fig. 23, *Fil. n.*) running longitudinally down the filament. It is connected with the branchial nerves to be described later.

The principal filaments differ in shape according to the level at which the transverse sections are cut.

If sectioned at about the level of the terminations of the ascending filaments, they have a **T** shape, owing to the frontal surface being much extended in an antero-posterior direction, the vertical limb of the **T** representing the interlamellar portion (fig. 21, *Fil. p.*).

The principal filaments have no connections other than by ciliated discs with the adjacent ordinary filaments. The ordinary cilia are to be found chiefly on two longitudinal ridges of columnar cells near the anterior and posterior edges of the frontal surface, but very short cilia are borne by all the cells on this surface.

The chitinous skeleton of the principal filaments is much more extensive and complicated than that of the ordinary filament. The most conspicuous and strongest part consists of two bars, somewhat triangular in section, which run longitudinally down the middle of the frontal surface just underneath the epithelium. The two edges of these bars nearest the frontal surface are fused, the chitin has a homogeneous structure and stains very deeply (fig. 23, *Ch. D.*).

From the outer sides of these two thickenings a strip of the same dark staining chitin extends in an interlamellar direction until it eventually reaches the walls of the filament, which it lines for some distance.

Extending from the sides of the two longitudinal bars, near the frontal surface, are two thick lateral expansions of a paler staining kind of chitin which extend, lying against the epithelium, along the whole extent of the frontal surface, and also line the sides, enclosing a space between them and the darkly staining portion. This pale staining variety of chitin has a more fibrous structure than the homogeneous central portion (fig. 23, *Ch. L.*).

The nerve branch passes down one side between the dark staining chitin, where it approaches the wall of the filament, and the epithelial cells, but between the nerve and the latter is a very delicate strand of chitin or connective tissue.

Several strands of tissue cross the filament, and the interlamellar margin is extended to form a membrane, which towards the lower free margins of the principal filaments extends completely across from the descending to the reflected portions.

The interlamellar junctions (fig. 23, *Br. j. l.*) which unite the two lamellae only extend about one-third of the height of the filaments, though the principal filaments develop interlamellar extensions along the greater part of their length.

This interlamellar extension, however, has a different character in two places. It is well developed on the descending portion of the principal filaments above the level of the free upper edge of the reflected lamellae, that is to say, in a position where there are no opposite principal filaments for it to be connected with (fig. 20, *Br. r.*). This expansion, which is found on each principal filament at its end nearest to the ctenidial axis, will be described below. It diminishes until it practically disappears at about the height of the upper ends of the reflected filaments, and then on the same side another expansion develops, which, more ventrally still, extends across to meet and fuse with its fellow on the opposite principal filament and form the interlamellar septum.

The first described expansion (fig. 20, *Br. r.*) may be termed the **respiratory expansion**, for it is probably here that most of the respiration is performed in the gills. It (see figs. 23, 24, 25) is formed of two bounding layers, a single cell thick, of epithelial cells, continuations of the sides of the principal filament. The space between them is bridged across at numerous intervals by one or two cells, serving to keep the two walls a definite distance apart. At the free margin of the expansion the two walls diverge to form a tube, circular in transverse section (fig. 23, 25, *Br. v.*), which is the channel for the blood.

The free margin of the expansion is attached some distance up the side of the ctenidial axis, and the vessel at its edge becomes directly connected with the afferent vessel of the gills (fig. 45, *Br. v. and Br. aff.*).

The structure of this expansion is more peculiar than it appears from transverse sections, and should be examined in surface view, the whole filament being stained and mounted in Canada Balsam. It then has a folded appearance, as if there were a series of pockets on the sides of a plane surface (fig. 23). A section parallel with the plane of the ctenidial axis shows that this appearance of pockets is simply due to an extensive folding having taken place, as if the greater part of the expansion had, through increased growth, doubled and re-doubled on itself whilst the free margin remained straight (fig. 24). Cilia are to be found on the free outer edge of the expansion, that is on the vessel itself, but do not appear elsewhere.

It will be best now to indicate the changes in detail in the various parts of the lamellae, and the mode of attachment of the filaments to the gill axis.

Commencing with sections through the ventral edge of the filaments, where they are reflected, there is a row of ciliated discs extending along the whole length of the lamellae, and serving thus to keep the filaments in position.

From this point the filaments take up their position so as to form the folds or plicae, but these are not very deep near the base of the lamellae (fig. 22). The principal filaments are as described above. Sixteen or seventeen ordinary filaments are, on an average, to be found between them. Both ascending and descending portions of the principal filaments are connected at this level by the interlamellar septum, which is very narrow.

As one passes by serial transverse sections from the ventral margin to the ctenidial axis the plications increase in depth, and the interlamellar septum is of greater extent until above a point one-third of the height of the filaments, the septum dies away in the middle, leaving an interlamellar expansion attached to both the ascending and descending portions of the principal filaments. The general character of the principal filaments still remains the same.

As we reach the level at which the ascending filaments end (fig. 21), the plication of the reflected lamellae decreases, and at the same time the filaments become more closely crowded. The principal filaments lose their **T** shape, and become more triangular in section.

From this point to the upper edge of the lamellae the chitinous skeleton of the principal filaments becomes more and more reduced, and at the same time the width of the filament diminishes, and its diameter from the frontal to the interlamellar surfaces increases. The ordinary filaments become more compressed and elongated as regards the fronto-interlamellar diameter, until the final result is that both the principal and ordinary filaments look exactly the same, and, owing to the increase in diameter, both kinds of filaments become spatulate at their ends. Some of the ordinary filaments become attenuated and do not reach the level attained by most of them, so that the number of filaments is reduced.

These spatulate terminations of the ascending portion of the filaments (figs. 20, 21, *Br. a.'*) are only united by stiff cilia. In one or two cases, however, in a whole series of filaments, two adjacent ones may be organically connected, but this is exceptional, and usually there is no connection between the upper ends for the circulation of the blood from one filament to another. Instead of there being a septum across the filaments at this level, there are numerous delicate strands crossing from one side to the other. Above the level of the reflected lamellae, the branchial interlamellar expansion is developed on the descending principal filaments, but they change their shape somewhat and the plications of the lamellae become deeper.

The main portion of the principal filament is now roughly rectangular, as fig. 23 shows. The chitinous skeleton is much more strongly developed, the two longitudinal bars can still be made out, but the lateral portions have thickened up considerably and have broad transverse connecting bridges. The pale staining chitin is present in the same position as in the sections cut lower down. Cilia are borne by the frontal edge as before, but owing to the increase in the depth of the plicae the adjacent ordinary filaments have their sides parallel to the frontal margin instead of being in the same relative position with their sides parallel to the sides of the principal filament.

The nerve (fig. 23, *Fil. n.*) can be seen embedded in the chitinous skeleton of one side, and there is also more connective tissue and muscle fibres in the filament.

The branchial expansion, which is on the interlamellar side, opens into the true cavity of the principal filament at one edge and into the longitudinal vessel running down the free margin of the expansion at the other. This brings us to the changes at the ctenidial axis, bringing about the attachment of all the filaments (text-fig. 2, p. 373). The lamellae are most plicate at this level, and the filaments closely crowded together. The first change is a permanent fusion of the ordinary filaments at the apex of the plicae, i.e. at the part of the fold most remote from the interlamellar side. This fusion is due to a development of connective tissue on the sides of the filaments near their interlamellar margins, that is, in the position where ciliated discs are found. The epithelium of the interlamellar margins of the filaments thus becomes continuous and cut off from that of the frontal surface. By further fusion of the filaments they eventually all become continuous; the principal filament also takes part in this fusion, so that there results a plicate lamella having the shape of the former plicae, but made up of organically connected filaments, traces of which are still seen owing to the epithelium on the frontal surface dipping into every former interfilamental gap. The epithelial walls of the principal filaments have become separated by a larger interval from the chitinous endoskeleton, that of the frontal surface becomes continuous with the epithelium of the frontal surfaces of the fused ordinary filaments, and that of the other side with the epithelium of their interlamellar surfaces.

The next series of sections, taken still nearer to the ctenidial axis, show that the grooves between the principal filaments, that is, the deep grooves which open to the interlamellar side, become reduced in depth owing to the fact that the development of connective tissue brings the epithelium of the fused interlamellar surfaces of the filaments more in a plane with the ctenidial axis. This means that the outer surface of the lamella tends to become a continuous plane surface, to which are attached the branchial expansions. The cavities of the ordinary filaments remain in their normal positions, and are far removed from the epithelium which once bounded their inner faces. Furthermore the nerves which ran down the inner edges of the ordinary filaments have become displaced with the development of connective tissue and are near the outer edges of the lamellae, they are much larger, and almost touch each other.

The outer margin, as soon as it becomes a plane surface, is continuous with the ctenidial axis. The expansions formerly on the principal filaments are continued over the outer surface of the axis for a little way, gradually diminishing in size until the level of the afferent branchial vessel is reached and the vessel of the expansion communicates with it.

The nerves from the various filaments, forming almost a lamella on each side, pass between the band of muscles which runs along each side of the gill axis (fig. 45, *Br. m.*) and the surface, and become connected with small ganglia or groups of ganglion cells, from which nerves pass up at the sides of the afferent vessel (fig. 45, *Br. aff.*) and connect on to the ctenidial nerve (fig. 45, *N. br.*). The presence of connective tissue and longitudinal muscles cuts off the cavity of the expansion on the principal filaments from the cavities of the principal filaments themselves, and further from all communication with the other filaments.

On the inner side of the plicate gill lamellae the epithelial layer tends to lose its plications and become a plane surface by the development of connective tissue;

but while this is going on as we approach the ctenidial axis, the same structure of the opposite demibranch is drawing very near to it, until both demibranchs fuse by their inner surfaces. The cavities of the ordinary filaments, bounded by their chitinous skeleton, elongate in a direction at right angles to the plane of the axis, until they eventually come in contact with those of the opposite demibranch, and thus we have the chitinous skeleton of both demibranchs and the cavities of the filaments continuous and all opening into the efferent vessel of the gill axis.

This elongation of the cavities of the filaments with their skeleton is probably only due to the sections passing through obliquely owing to the filaments of both sides curving over as the chitinous framework becomes continuous. Thus the blood, which has been forced to the various parts of the body with the exception of the mantle, and has been collected and taken to the renal organs (fig. 16, *Ro.*), passes from these on each side by the afferent branchial vessels (fig. 45 and fig. 16, *Br. aff.*), and then from these laterally into the vessels running down the margins of the branchial expansions of the principal gill filaments. From these vessels it can pass into the expansions themselves, the whole of which act, therefore, as respiratory surfaces. This brings the blood into the principal filaments, from which it passes into the efferent branchial vessel running just below the afferent. Since the ordinary filaments only open into the efferent vessel, the blood that passes through them must be partially aerated, and there will in all probability be no definite current, but a backwards and forwards motion. It seems certain, from the development of vessels in the mantle, that the great function of the gills is to produce currents of water for aeration, nutrition, and the carrying away of waste products, and the only parts of the gills performing any really important duty in respiration are the branchial expansions of the principal filaments.

ALIMENTARY CANAL AND DIGESTIVE GLAND.

The Alimentary Canal of Pecten is comparatively simple, and there are no complicated convolutions in the visceral mass as in Cardium. The total length is about twice that of the longest antero-posterior diameter of the body.

In order to examine the alimentary canal, it is necessary to remove the mantle and gills from the right side, and it will be easier if the specimen has been left for a day or so in 5 per cent. aqueous solution of formol.

The course of the alimentary canal in the visceral mass can be best made out by shaving off slices parallel to the surface. Sections will also best show the shape and position of the stomach.

The mouth (fig. 39, *M.*) is situated between the lips which are conspicuous dorsal to the foot (fig. 39, *Lp. u.*, *Lp. l.*). It is hidden completely by them, and food particles pass into it by being carried forward at each side of the visceral mass and foot between the labial palps.

The Labial Palps (figs. 1 and 39, *L. p. e. and L. p. i.*) consist of an inner and an outer broad flap on each side of the visceral mass at the points where the gill lamellae terminate dorsally. The outer is a continuation of the upper lip, and the inner palp of the lower lip. They are pigmented yellow-brown, but are very thin and somewhat transparent. The inner palp is rectangular in shape, and is attached to the visceral mass along the inner long edge and the short ventral edge. The attachment is, however, confined to these two edges, and the whole area is therefore free. The attachment of the ventral side is situated on a small protuberance on the side of the gonads. The dorsal short side passes into the upper lip. The outer labial palp is rather more triangular; the attachment is by the proximal side, and mainly to the visceral mass at the side of the digestive gland; the lower end, however, is prolonged slightly, and is attached to the mantle.

The attached sides of the palps join one another, so that a palpar gutter is formed, along which food particles are conveyed to the mouth. The two apposed surfaces of the labial palps are grooved (fig. 40); the other two surfaces are plane. The ridges run across the surface almost at right angles to the attached side, that is directly across the direction taken by the food current, and have their crests directed orally so as to facilitate the passage of particles in that direction and prevent their return.

The plane outer surfaces of the palps are bounded by a layer of cubical non-ciliated epithelial cells (fig. 40), which are pigmented and include a few scattered sense cells. The grooved surfaces are bounded by a layer of much elongated ciliated cells. Those on the summits and sides of the ridges are, however, much longer, and bear more cilia than the cells at the bottom of the grooves; scattered sense cells occur. The rest of the palp is composed of loose connective tissue with scattered nuclei, and numerous spaces with blood corpuscles. A few muscle fibres form a somewhat diffuse layer not far from the surface, and there are in addition nerves from the cerebro pleural ganglia.

The Lips are continuous with the labial palps; the upper with the two external palps, and the lower with the internal. They are, in Pecten, very extensive, highly-developed structures, and very characteristic in shape (fig. 39). They consist essentially of two transverse ridges of tissue, very similar, histologically, to the palps, but without the grooves.

These two ridges, however, are produced in certain places into prolongations, which, as well as the free edge of the lips generally, divide and re-divide into very small, short and swollen processes. In this way the lips come to have a dendritic appearance. There are two main prolongations of the upper lip with dendritic margins, situated one at each side near the origins of the labial palps. The lower lip has a very large median prolongation which interlocks with those above, and lesser ones along the sides. It seems, therefore, that this development of the branched margins is for the purpose of closing over the mouth, leaving a channel which communicates at each side with the groove between the two labial palps.

The margins of the lips are deeply pigmented with the same orange-yellow that is found on the palps, and also lining the oesophagus.

The upper surface of the upper lip and the lower surface of the lower lip are bounded by a layer of epithelial cells, which are almost cubical in shape, and are crowded with pigment granules, especially near the surface. This layer is continuous with the somewhat similar layer that covers the outer surfaces of the labial palps. The surfaces of the upper and lower lips, which face one another and are continuous with the grooved surfaces of the labial palps, are bounded by a layer of much elongated columnar cells, which contain no pigment, but bear numerous cilia. The structure between these two layers is loosely packed connective tissue, with numerous spaces containing blood corpuscles. A slightly denser layer immediately underlies the epidermis.

The mouth itself (fig. 39, *M.*) is a transverse slit leading into a rapidly narrowing oral cavity, which contracts into the narrower width of the oesophagus (figs. 1 and 36. *Al. c. 1*). This latter is a tube about ½in. long in *P. maximus*, dorso-ventrally compressed and leading upwards and posteriorly to the stomach. The opening is not at the anterior end of the stomach, but a little further back and on the roof—rather to the right side in *P. opercularis.* Both the oesophagus and stomach are completely enclosed by the digestive gland, the so-called liver (fig. 1, *Dg.*) The oesophagus is lined by a thick epithelial layer, slightly marked by transverse ridges, which has the same yellow-brown colour that occurs so frequently, and which contrasts strongly with the dark green digestive gland surrounding it. The cells forming the epithelium are long, narrow and ciliated. The height of the cells is many times the width, but since there is very little difference between the cells lining the various parts of the alimentary canal, a fuller description will be given later. Outside the epithelium there is a basement layer of compact connective tissue, and, outside this, looser connective tissue with transverse and longitudinal muscle fibres, which is connected with the strands that separate the tubules of the digestive gland.

The stomach (figs. 36 and 38, *Al. c. 2*) lies in the midst of the digestive gland, but usually nearer to the left side than the right. It is of very irregular, roughly oval shape, with the longest diameter antero-posterior, and with irregular folds and depressions breaking up the wall into certain areas. Two of these on the left side and one on the right are more important than the others and occur with greater regularity. On the left side, not far behind the level at which the oesophagus opens, there is a crescentic, anterior, left lateral depression (fig. 38, *Al. c. 2′*), and a little behind this is another almost circular posterior left lateral depression leading into a short caecum (fig. 38, *Al. c. 2″*). Into the first there open four to seven ducts ("bile ducts") from the digestive gland, and into the second there are about three openings. These ducts are situated on the side walls in *P. maximus*, and are very numerous. The number is, however, variable and difficult to make out, as in some cases ducts may join before reaching the stomach. On the left side they all open into the two depressions mentioned. On the right side there is an antero-posterior groove into which as many as ten ducts may open. The stomach is usually found to contain the remains of vegetable matter. The walls are lined by a gelatinous-looking substance, found also in other lamellibranchs and known as the "fleche tricuspide": this will be considered later along with the crystalline style, of which it is in all probability a part.

The epithelium of the stomach is for the most part a smooth layer, but on the left side the lining of the posterior wall of the anterior depression has a number of delicate ridges separated by grooves, leading from the openings of the ducts into the main cavity of the stomach. It is on the right side, however, that this grooved epithelium is best seen, and it forms quite half of the wall, extending from the whole width of the crescentic depression to the opening of the intestine, towards which the grooves are all directed. The grooves are not separate and parallel along their whole length, but open into one another as the intestinal opening is reached. This epithelium of the stomach rests on a basement membrane of almost structureless connective tissue. Outside this there is a muscular layer made up of fibres running in different directions, but chiefly transversely. External to the muscle layer, and between it and the digestive gland, are numerous large spaces, crowded with blood corpuscles, amongst which are large spindle-shaped connective tissue cells, the ends of which are drawn out into long fibres.

The epithelial cells lining the cavity of the stomach are very long and narrow, the length attained averaging about 0·07 mm They have prominent elongated nuclei situated at about the middle of their length. These, like the epithelial cells throughout the whole length of the alimentary canal, are richly ciliated.

If sections be cut transversely across the grooved epithelium it will be seen that the grooves and ridges are due to the varying height of the epithelial cells; those which lie at the bottom of a groove are only one-quarter of the height of those forming the ridge. The cell contents are the same in the two cases, and the cells at the bottom of the grooves bear just as well developed cilia, so that they apparently function as channels along which the secretion of the digestive gland passes. Some of the cells (but not those of the grooved epithelium) contain large and small green granules, which are sometimes as wide as the cell, and lie in a distinct vacuole.

THE DIGESTIVE GLAND.

This large gland (fig. 1, *Dg.*), which is the only one occurring in connection with the alimentary canal, has at various times been known as the liver, the Hepato-pancreas and the Gastric gland. The only function that entitles it to the name "liver" is that of apparently forming or certainly of storing fat and pigment. After much investigation, it now appears to be a "pancreas" with the additional function of storing pigment, and in some Lamellibranchs (*Ostrea*) large quantities of fat. It is better, however, to term it simply "digestive gland," for it is evident from experiments that it secretes ferments which perform functions that are specialised in separate organs in higher animals. It is conspicuous both from its size and its very dark colour, due to the contained pigment. The gland itself is of a more solid consistency than is usually the case in Molluscs. It lies dorsally to the adductor muscle, against the ligament, which causes a depression on its surface.

The gland completely wraps round the large stomach, and there is no sign of a division into two lobes in its compact mass except that the ducts open in two series laterally into the stomach, as has already been pointed out.

The gland may be fixed for sectioning in Flemming, Mann's Fluid or by McMunn's method, that is by placing pieces of fresh gland in 20-30 per cent. formol for 12-14 hours, and then in 95 per cent. alcohol.

The green pigment can be seen *in situ* whether fixed in formol or by Mann's Fluid, though it is dissolved out readily by spirit, if placed directly into it.

It (fig. 50) is a tubular gland formed by the ducts dividing up into numerous branches, which, ramifying on their way, divide still further to form caeca.

In Pecten this makes up practically the whole of the gland, for there is no great development of vesicular connective tissue as seen in the oyster. Moreover, in the latter the secreting alveoli are to be seen in sections as tubes with a considerable cavity. In Pecten they are very short, and soon become wholly solid in character, so that the first difference which one notes on comparing sections of the two glands is the solidity of the one and the tube-like alveoli of the other. It is difficult to divide the cells lining the ducts into different categories, for one kind seems to be gradually transformed into another, and probably there is only one type of secreting cell present.

The ducts (fig. 50) conveying the secretion to the stomach divide up in the gland into several branches lined with ciliated epithelium. The cells are columnar and granular in appearance, with a prominent nucleus near the base. They are supported by a layer of connective tissue the *tunica propria* (fig. 50, *Tu. p.*). Outside this, again, is a layer of circular muscle fibres, which pass round the duct forming the *tunica muscularis* (fig. 50, *Tu. m.*) "Macroblasts," or eosinophilous cells, as seen in the oyster, are not present in Pecten, though under the action of the same fixatives and stains they show up strongly in the mantle.

The only type of cell present appears to be the granular cell lining the alveoli (fig. 50, *Al.*), but smaller cells can be observed between some of these, which stain much more intensely than the others. These are probably similar to the cells described by MacMunn (**21**) in the gastric gland of *Patella*, and are young cells which will replace the others, for, in sections through the alveoli, the granular cells can be seen in process of being shed into the lumen, and there are bodies in the course of the ducts, of common occurrence, that are undoubtedly these shed cells on their way to the intestine. In this way the digestive gland appears to have an excretory function in addition to its storing and pancreatic functions. Pigment concretions do not appear in the lumen of any of the alveoli. Cilia are confined to the ducts, and as an alveolus is followed towards its caecal end the cells become fewer and more swollen (fig. 5, *Al.'*) and intensely vacuolated, the nuclei lying against the connective tissue membrane supporting the cells. Eventually the lumen of the alveolus disappears altogether, and the cells meet in the centre (fig. 50, *Al.*"); their protoplasm has practically disappeared, there are just a few strands left crossing the cells which contain the green pigment granules clustered together in little groups. The connective tissue membrane bounding the alveolus has here become very thin, and the circular muscles have practically disappeared. MacMunn (**21**) has termed the green pigment enterochlorophyll, and finds that the spectrum given by the spectrophotometer is almost exactly that of plant chlorophyll modified by the addition of a little acetic acid acting for several hours. He considers, therefore, the pigment to be modified chlorophyll. Miss Newbigin considers the resemblance of this pigment to chlorophyll to be only superficial, and places it in the same category as Chaetopterin and Bonellin.

It is, however, almost certain that the colour of the digestive gland at any time is dependent on the colour of the food, and several observers, including List and Dastre and Floresco (**6** and **19**), have shown that if Lamellibranchs are fed with colouring matter this appears in the form of small granules in the cells of the digestive gland, and even after two hours can be traced there. List shows, further, that it is a direct absorption, and not a function of the wandering cells.

In order to determine the action of the secretion of the digestive gland, the following bio-chemical experiments were undertaken. They confirm those of Roaf (**22**) on the glands in other molluscs.

The glands were taken from several Pecten, the whole mass weighed and then minced up in a definite volume of distilled water to which a little HCN (or toluol when testing for sugar) was added as a preservative. This was allowed to stand for twenty-four hours and then strained through muslin and a series of solutions made up, each containing a definite amount of the extract, together with the substance to be acted upon. The "liver" extract was neutral, perhaps, if anything, slightly acid in reaction to litmus. The following were the various experiments made :—

(1) 5cc. $\frac{N}{10}$ HCl + 4cc. dist. H_2O + 3cc. extr. + ·5gr. fibrin.

(2) 5cc. $\frac{N}{10}$ Na_2CO_3 + 4cc. dist. H_2O + 3cc. extr. + ·5gr. fibrin.

(3) 9cc. dist. H_2O + 3cc. extract + ·5gr. fibrin.

(4) 5cc. $\frac{N}{10}$ Na_2CO_3 + 4cc. dist. H_2O + 3cc. extr., allowed to stand three hours, and made acid.

(5) 5cc. $\frac{N}{10}$ HCl + 4cc. 2 % peptone + 4 cc. extract.

(6) 5cc. $\frac{N}{10}$ Na_2CO_3 + 4cc. 2 % peptone + 4cc. extract.

(7) 5cc. $\frac{N}{10}$ H_2O + 4cc. 2% peptone + 4cc. extract.

(8) 5cc. 1% Methyl Acetate Sol. + 2cc. extract.

(9) 5cc. 1% Methyl Acetate Sol. + dist. H_2O (as control).

To each of these two drops of HCN were added as a preservative.

(10) Extract + Starch Solution ; toluol as preservative.

After allowing the various mixtures to stand for forty-eight hours, the following tests were made :—

The residues from 1, 2, 3, 4 and 7 were divided into three parts respectively, and the following products of digestion sought for :—peptone or albumoses, tyrosin, and tryptophane.

The Biuret test consists in the addition of one drop of $CuSO_4$ sol. and then KHO : a rose coloration indicates albumoses, a violet colour indicates unchanged protein.

Tyrosin is tested for by adding Millon's reagent to a portion and filtering off the precipitated proteid; the filtrate becomes red on boiling, if tyrosin is present.

Tryptophane gives a reddish violet colour with bromine or chlorine water.

The results were as follows:—The fibrin was all digested in the acid solutions (1) and (4); about three-fifths on the average was left in the alkaline mixture (2), and a little less in the neutral (3). The biuret reaction was very good in (1), medium in (2) and (3). Tyrosin reaction was good in (1), medium in (2), and fair in (3).

There was practically no tryptophane in any of them. It will be noticed, therefore, that digestion proceeds best in acid media, the reverse of the process in the Crustacea. With the peptone solutions (5), (6) and (7), though the same tests were made, it was a diminution of the biuret tint that was looked for, since digestion would convert the peptone into more simple products. The results were almost negative; the residues all gave a strong biuret reaction and no tryptophane; the tyrosin reaction was good, but it was found later that the peptone itself gave this reaction. If there are therefore any ereptic ferments present, they are in small quantities only.

Experiments (8) and (9) were for the purpose of testing for fat digestion; the methyl acetate was broken up into acetic acid, which was estimated by titration with decinormal sodium hydrate in presence of phenol phthalëin.

No. (9) was a control, and required 1·3 c.c. $\frac{N}{10}$ NaHO to neutralise it, whereas No. (8) required 10·6 c.c. $\frac{N}{10}$ NaHO to neutralise it and smelt strongly of acetic acid.

No. (10), after standing 48 hours, gave NO blue colour with Iodine, the starch had all been hydrolysed.

The secretion of the digestive gland is capable, therefore, of acting upon proteids, starch and fats, or, in other words, it contains proteolytic, amylolytic and lipolytic ferments, like the pancreatic juice of vertebrates. The action of these ferments is to convert colloid materials like starch and proteid into the diffusible materials, sugar and peptone, which are eventually absorbed; and the intestine must be considered as the place where this absorption is going on, the descending limb from the stomach being probably the main portion concerned.

The intestine may be divided into three sections, which are of practically the same length: (1) the descending portion (fig. 36, *Al. c. 3*); (2) the ascending portion (*Al. c. 4*); and (3) the rectum (*Al. c. 5*).

(1) The descending limb of the intestine arises from the stomach, not posteriorly, but ventrally, at almost the middle of its length, and passes anteriorly and downwards from the stomach through the digestive gland to the reproductive region of the visceral mass (fig. 1). At the level of the foot this portion of the intestine lies amidst the tubules of the gonad, in the median line, very near to the surface of the visceral mass lying against the adductor muscle. From this point it curves forwards towards the free margin of the visceral mass, and in *P. maximus* extends down to the extreme end of the latter, where it bends suddenly and returns as the (2) ascending limb. This lies close to the adductor surface all the way and at first in the median line, but when the point is reached where the descending portion comes near to the adductor, the ascending portion is displaced and lies to the right of it, so that it eventually plunges into the digestive gland on the right side, and lies near the surface on the right side close to the adductor muscle. It passes up to the dorsal surface of the gland, where it lies in the

median line exactly under the anterior aorta. It now enters the pericardium and passes through the ventricle of the heart.

The course of the alimentary canal in *P. opercularis* is somewhat different, but only in the visceral mass. Instead of the descending limb passing down to the end of the reproductive region, it stops short at about the junction of the seminal portion with the ovarian, and forming a loop at this point returns to the digestive gland as the ascending limb, without passing through the ovarian region at all.

The descending portion of the intestine in transverse section (fig. 37) is almost circular, but owing to differences in the cells lining the cavity, there is a trace of division into two compartments. The larger part of the cavity is lined by epithelium cells, which are elongated and many times their width in length (fig. 42). Most conspicuous, however, are the cilia which they bear. These are strong looking, of considerable length, and present in great numbers. These cells have finely granular contents, and often contain large granules of a green colour. Separating this region from another to be presently described are two ridges situated opposite one another (fig. 37), and formed of epithelial cells about twice as long as those previously described, but their cilia are not so numerous nor as strong, and the cells do not contain the round green granules. The cells lining the smaller cavity (fig. 37, *Al. c. 3′*) are much shorter than any of the others, being only about a quarter as long as those of the ridges. Like those cells, they bear much shorter and weaker cilia. The division between these two parts of the intestine is but slight, and the differences are due to the character of the cells. Projecting into the larger compartment of the intestine (fig. 37, *Cris.*) from the stomach is a gelatinous rod, the Crystalline Style (fig. 36). In dissections it seems to fill the whole lumen of the alimentary canal at this point, though belonging, as pointed out, to the one compartment, for microscopic sections are necessary to see the separating ridges. Pecten shows a primitive condition in that the style lies in the intestine, but other forms are known connecting this with the complete separation of a crystalline style sac, appended to the stomach. There has been a great amount of discussion with regard to the origin and function of the crystalline style, almost every writer formulating a new theory, one or two of which will be considered here. The style has been regarded:—(1) As playing a part in the act of generation (von Heide, Cailliaud); (2) as a rudiment of the radular sac of the Glossophora (Balfour); (3) as acting mechanically upon the food under the action of the digestive fluids (Milne Edwards), or serving to bring the food particles between the style and the dense cilia of the epithelium (Sabatier); (4) as preventing the food from passing too quickly through the alimentary canal before it has time to digest (Kellogg); (5) as a reserve food material (Hazay, Haseloff; (**24** and **25**); (6) as an excretion (Claus); (7) as lubricating the undigested food particles passing through the intestine (Barrois) (**23**); (8) as an active digestive ferment (Mitra) (**26**).

In *Pecten maximus* the style is large, sometimes attaining a length of three inches. It is circular in transverse section, and widest near the stomach into which it protrudes. From here it tapers to a point near the end of the descending limb of the intestine. The upper end is sometimes rounded and enlarged, forming a knob; at other times it is connected with the gelatinous lining of the stomach, and it seems certain that this "fleche tricuspide" and the crystalline style are continuous and have the same structure and function. The fresh styles are flexible, and very elastic. The colour is a translucent brownish-yellow. In some cases the style, when removed from the intestine, came out quite clean. On other occasions there was a beautiful spiral of green substance (like the matter found in the stomach and rectum) encircling it, as shown in fig. 36. It might also have a dark axial portion. In cross section (fig. 46, *a.*) under the microscope, the substance of the style is seen to be perfectly homogeneous, with no organised structure and generally with but little difference between the substance forming the axis and that of the periphery. There is, however, a very distinct laminated appearance, as if the style were formed of concentric layers of a colloid substance, and this gives it a striated appearance in longitudinal section. The dark axis that occurred in one specimen was due to a thick dark ring which was apparently formed of a similar substance to that found encircling the outer surface of some of the styles and, like it, arranged in a spiral manner. The concentric dark rings seen in transverse section are also probably due to the same green food matter from the stomach. Barrois, in a detailed account of the structure and physiology of the style (**23**), gives descriptions of the chemical composition and reactions; and these are borne out by the later work of Mitra, whose analyses show that there is about 88 per cent. of water in the style, about 12 per cent. of proteid, and about 1 per cent. of salts. The style is slowly soluble in water, and the solution is neutral. The tests made on the style of *Pecten* agree with those of Mitra on *Anodon* (**26**) and Barrois on *Cardium* (**23**).

The presence of proteid was indicated by the xanthoproteic reaction (a white precipitate is given by addition of nitric acid to the solution, which turns yellow on boiling and, after cooling, becomes orange on the addition of ammonia). Millon's reagent, when added to the original solution, gave a white precipitate, turning brick red on boiling. The Biuret test also indicated proteid. The concentrated solution is coagulated on heating. The proteid as shown by Mitra belongs to the Globulin class.

With regard to the physiological properties of the style, the following must be noted. It disappears when the animals are kept in sea water free from nutriment of any kind. This has been shown to be also the case in Anodon. After transit Mitra found that fifty might be opened without showing any trace of the style, whereas if placed in a fresh-water aquarium with plenty of food, it was invariably present after an interval of a few hours. Mitra also states that his mussels were not able to carry on respiration and nutrition actively during the night, owing to a leakage in the tank containing them, with the result that the style was absent when mussels were examined at eight o'clock in the morning, and the digestive function was also in abeyance.

Two or three hours afterwards the style would be present. In the case of Pecten such rapid alterations were not found, but specimens kept in a tank which was simply aerated by an air current, and in water which was practically free from food matter, were always found to be without the styles.

It seems that the presence of the crystalline style is concerned with digestion, and it is interesting therefore to find that it contains a digestive ferment.

To test the action a solution of several styles was made up and allowed to act on a starch solution for some hours, precautions having been taken, as a control, to test first for sugar in the reagents. At the end of the time some of the starch had been hydrolysed, and the solution now reduced Trommer's and Fehling's solutions. The phenyl hydrazine test also indicated the presence of sugar.

Mitra was the first to show that the crystalline style contained a digestive ferment (**26**), which was able to convert starch and glycogen into sugar. He assumed from this that the work of the crystalline style was that of a ferment. Now, though I have found the ferment in the styles of Pecten, the amount of starch which was hydrolysed was small, and it is possible, especially if the style be regarded as a secretion of the digestive gland, that the presence of a ferment is accidental.

With regard to the question of the origin of the style, the tricuspid body and the latter have exactly the same structure, and in some specimens appeared to be continuous. Further, the tricuspid body is in close connection with the lining of the stomach and extends into the pockets and openings of the ducts from the digestive gland. I think it probable, therefore, that the style is secreted by the digestive gland. The cells of the alimentary canal, with their long cilia, have not exactly the appearance of secreting cells.

With regard to the various theories named above, there are serious objections to most of them. The style cannot, moreover, be looked upon as a rudimentary structure, since the compartment of the intestine in which it is lodged, and the special caecum of the other lamellibranchs are lined with better developed cilia than the rest of the alimentary canal. The theory of Barrois (**23**) that diatom frustules, &c., are encased by the substance of the style seems hardly sufficient reason for the development of a special caecum and style, when there is no such organ in ascidians, echinodermata or worms, which have similar food matters.

The nature of the style is decidedly not that of a reserve food material, and it seems difficult to comprehend why, under normal conditions, marine lamellibranchs should require to make provision for times of starvation.

Barrois, who rejects the theory of reserve food material, states that he was never able to detect a diminution in the styles at various seasons nor even after keeping specimens of Cardium in filtered water for some days. Both Mitra's experiments and my own confirm Hazay and Haseloff (**24** and **25**) as far as this is concerned, and the chief objection to the reserve food stuff theory must be the composition of the style itself. The position of the style and its composition tell strongly against the theory of it being an excretion. When the animal is kept under such conditions as described by Mitra, is it absorbed by the animal or simply dissolved away by water passing through the alimentary canal? Possibly it is absorbed and the ferment used for converting the glycogen (which is stored up in large quantities in most lamellibranchs) into sugar.

The development of a caecum certainly points to a storage for some purpose. There is no doubt that in Pecten, where the style seems to occupy the whole area of the intestine, it hinders the food from passing too quickly through the alimentary canal, and provides an additional surface over which its contained amylolytic ferment can act. It must be remembered, however, that the presence of this ferment in the style is not conclusive proof that the style has been evolved as a ferment or method for storing a ferment.

It has been already stated that the last portion of the intestine passes through the pericardium and the ventricle of the heart. Here, as in many other lamellibranchs, we must assume that the ventricle has grown up around the alimentary canal, so that the wall of the heart lies between its cavity and the walls of the alimentary canal. Outside the usual lining epithelium there is a basement membrane of connective tissue with a few circular muscle fibres, and external to that a thick sheath of looser connective tissue. The epithelial cells (fig. 44) resemble in appearance those of the ascending limb of the intestine. They are deep columnar cells, the height being many times the diameter, and the cilia are rather poorly developed. The ends of the cells facing the cavity have a strange appearance, as if either a part or the whole cell were being shed into the lumen of the intestine. These shed cells seem to have no stainable contents and no signs of nucleus, and when cut off completely appear in the intestine as spherical bodies faintly stained but with a very definite wall. Lying scattered amidst the connective tissue surrounding the intestine, especially in that part passing through the pericardium, are conspicuous wandering cells, pear-shaped, with most of the protoplasm and the nucleus at the narrow end, and a very large vacuole taking up practically the whole of the rest of the cell. There is generally a large mass of dark yellowish green material in this vacuole, which renders these cells very obvious. The same cells are found in considerable numbers, and carrying the same pigmented contents, in the connective tissue of the digestive gland. It is impossible, however, to say whether their function is excretory or nutritious, and whether the coloured contents are extruded by the cells lining the alimentary canal or not, but they resemble so closely those of the pericardial gland on the auricles, which are excretory, that they are presumably the same.

The epithelial cells lining the ascending portion of the alimentary canal contain numerous granules like food granules, and the same green tint is present here also. It would seem from this that the pigment of the digestive gland is derived directly from the food taken into the alimentary canal.

The rectum, after passing through the pericardium, continues its course over the adductor muscle under the connective tissue sheath. It does not run in the median line, but crosses towards the left side. At about the level where the circular muscles of the mantle edge are inserted to the shell the rectum leaves the adductor, and for its last centimetre is free. The anus is surrounded by a prominent lip.

BLOOD SYSTEM.

The blood system which has been worked out in *Pecten maximus* is very complete, and, like the vascular system of lamellibranchs in general, is entirely closed, so that water cannot enter the circulation directly. There is, moreover, no communication between the heart and the pericardial cavity, and this does not contain blood. The system comprises true vessels, mainly arteries, which are large and easily followed in injections, but the venous system is much more lacunary in character. The amount of blood is considerable, and when the adductor muscle has been cut, on opening the shell as much as 25 c.c. of blood have been obtained from one specimen. The blood is a colourless fluid slightly thicker than water, with a strong saline taste. As is general for aquatic invertebrates, the osmotic concentration of the blood is practically the same as that of the sea water in which the specimen has been living, and small changes in the concentration of the outer medium are followed by the same changes in the blood. The Δ or lowering of the freezing point for some examples taken at Port Erin was as follows (Beckmann's Freezing Point apparatus used):

Sea water in which Pecten were living		Δ – 1·910
Blood from *P. maximus*	- -	Δ 1·910
.. .. ..	- -	Δ –– 1·905
.. .. ..	- -	Δ — 1·920

An oyster or cockle placed in fresh water might live for some time without any change taking place in the osmotic concentration of the blood. This, however, is simply due to the animal closing the shell valves and completely shutting out the external medium from any contact with the body. In Pecten, on the contrary, as already pointed out, the two shell valves do not close perfectly, and, moreover, the animal persists in clapping the valves, so that a change in the outer fluid is followed by a change in the blood and immersion in fresh water proves fatal. The electrical conductivity is slightly less than that of sea water. If the blood is allowed to stand, after being drawn, the mass does not become jelly-like by coagulation as does crustacean blood, but a white precipitate forms, often in one large mass. The process can be watched under the microscope, and the precipitate will be seen to consist wholly of leucocytes which have collected together and left the fluid portion of the blood practically free from them. The leucocytes are amoeboid corpuscles which have fine bristle-like pseudopodia, often branched and by means of which they can move slowly (fig. 7, *L.*). Sometimes these narrow bristle-like pseudopodia prove to be the edge-view of flattened lamellae. When the blood is exposed to the air, the corpuscles collect together, becoming entangled by the pseudopodia, and in this way *clumps* are formed (fig. 7, *L. cl.*). The boundaries of those near the margins can be traced, but in the centre of a large clump all trace of a cell outline seems to have disappeared and a plasmodium is formed. This probably has the same function as the clotting in crustacean and mammalian blood, but differs in that there is no development of fibrin in the blood plasma which remains fluid on standing in the air, or even on heating. The same feature appears to be present in the coelomic fluid of some other invertebrates (**16**).

The blood as a whole appears to contain very little nutritive matter. In stained sections the leucocytes in the organs are round or oval, with retracted pseudopodia, and a prominent nucleus containing smaller dark bodies.

The central organ of circulation, the heart, is situated on the dorsal posterior side of the large adductor muscle, posterior to the digestive gland, against which it lies. It is contained in a pericardial cavity (fig. 1, *Per.*), which is bounded above by a fibrous roof connecting the two mantle lobes, while anteriorly it is prolonged, forming two deep pouches which extend above the adductor muscle and between it and the digestive gland.

The pericardium is the representative of the coelom, and communicates with the exterior by a pair of excretory organs, which are coelomoducts. The pericardium is lined by a thin endothelium formed of flat cells.

The heart consists of a ventricle and two auricles (fig. 13, *Ven.* and *Aur.*). The ventricle is a large spongy sac, the cavity being cut up and reduced in size by numerous muscle fibres which cross in all directions. When contracted the size is very small. The shape is roughly that of two triangles, with their bases apposed, except posteriorly, and with the apices, which are rounded, opening into the auricles. The ventricle has grown up round the rectum and encloses it (fig. 13, *Al. c. 5*, and fig. 43), as in the majority of lamellibranchs. The wall of the ventricle is composed of a layer of epithelial cells on the outer side, resting on a delicate basement membrane of connective tissue. Internal to, and lying against this latter, are the muscles, which run across the ventricle in all directions, imbedded in a granular matrix which sheathes the bundles of fibres. There appears to be no striation on these fibres.

The **Auricles** are two large chambers, one on each side of the ventricle, and having a brown tint. Their shape is roughly conical, the base being uppermost and communicating on each side with the ventricle, and opening by their narrower ends into the vein bringing blood from the gills and mantle to the heart. In Anodon and many other lamellibranchs the triangular auricles communicate with the efferent branchial vessel by the whole length of the base, and the narrow end opens into the ventricle. The position in Pecten may indicate the primitive molluscan arrangement, with posterior ctenidia.

The walls of the auricles are not smooth like those of the ventricle, but are raised all over into papillae, representing depressions of the inner surface (fig. 13). This peculiar papillated appearance is best seen when the auricle is distended by blood or injection, and is no doubt a device for increasing the area of the auricular walls for the purpose of excretion by means of the pericardial gland. This is confined to the surface of the auricles in Pecten, and gives the brown colour. It will be described later with the other excretory organs.

The auriculo-ventricular openings are guarded by a series of circular fibres which function as valves and prevent the blood being forced back into the auricles. The auricles are also connected with each other by a broad transverse branch ventrally resting upon the floor of the pericardium (fig. 13, *Aur. C.*). The heart beat is slow, an average of about twenty-five to thirty contractions per minute. It is necessary to inject the blood system to follow its course, and owing to the fact that the digestive gland is of a very dark colour, whilst the visceral mass is, on the other hand, of a light tint, injections must be made with both light and dark colours, in order to determine the course of the blood vessels in all parts of the body.

A great part of the vascular system can be made out by using an injection mass formed of a mixture of lard, linseed oil, and yellow oil paint (chrome yellow, as sold in collapsible tubes, will do very well), in such a consistency that it will run fairly easy (a little less viscous than glycerine). Care must be taken not to have any solid particles left in the coloured mass. It is necessary to prepare the specimens, for it is useless attempting to inject the living animal since the contraction of the muscles closes up the vessels. The necessary state of muscular relaxation can be produced by placing the animals in a bucket of sea water and adding slowly, at intervals, to the surface some of the following mixture: 100 c.c. 75 per cent. alcohol, 100 c.c. glycerine, and 200 c.c. sea water. In about eighteen to twenty-four hours, the specimens were narcotised and could be transferred to formalin (5 per cent. solution) for about half an hour without further contraction; they were then ready for injection. For the arterial system, the best point of attack was found to be the efferent branchial vessel (fig. 16, *Br. eff.*), in the ctenidial axis, with the point of the syringe directed towards the heart. This will inject the anterior and posterior aortae, the adductor artery, and in fact the whole of the arterial system, together with the mantle or pallial vein.

In order to inject the venous system the syringe can be put into the afferent branchial vessel (fig. 16, *Br. aff.*). Care must be taken that the tissue separating the two branchial vessels is not perforated. Further, when injecting the venous system, the valves must not be removed, but the convex valve should be broken away carefully, piece by piece, with bone forceps, right up to the attachment of the adductor muscle to the shell. The muscle must not be separated from the valves, for a large sinus will be otherwise broken into. If the oil mixture is used for both these injections the course of many of the main vessels can be followed, but it is not permanent and will not allow of the dissection of arteries and veins in the visceral mass and other deep-lying parts of the body. For this latter purpose, ordinary table jelly coloured with carmine, and melted with just a little water, proved quite satisfactory. It is necessary, previous to injecting with the hot jelly, to place the specimen in warm water for about half an hour.

ARTERIAL SYSTEM (fig. 14).

The blood leaves the ventricle by two main vessels, the anterior and posterior aortae.

The Anterior Aorta (figs. 14 and 19, *Ao. ant.*) is a large artery which arises from the ventricle at the middle of its dorso-anterior edge above the alimentary canal, and passes forwards directly over the latter to the digestive gland. There is an aortic dilation just after leaving the ventricle, inside the pericardium, and this can be seen to expand after each contraction of the ventricle.

On reaching the posterior end of the digestive gland the aorta passes dorsally along its middle line, giving off a small vessel on each side (figs. 14 and 19, *a.*) which pass over the surface of the gland along its posterior lateral margins, providing numerous branches, and eventually plunging below the surface into the substance of the gland. Other small branches are given off, on each side, from the aorta, and pass through the gland to supply the stomach.

Approaching the pit wherein the ligament rests, the aorta curves to the right of the median line so as to bend round the pit, and on reaching its anterior edge plunges down into the midst of the digestive gland, bending slightly to the right, so as to pass the oesophagus on that side. It gives off two vessels, which arise close together on the left side. Both of these leave the gland and pass into the mantle, one curving back to supply the region of the ligamental pit; whilst the other, the anterior pallial artery (fig. 14, *A. p. a.*), which is larger, passes forwards to the anterior dorsal corner of the mantle, where it bifurcates to form the circumpallial arteries running round the margin of the mantle lobes. It also gives off smaller vessels before dividing, which supply this area of the mantle on both sides.

The main branch of the aorta passes, as we have seen, into the midst of the digestive gland (fig. 14), and gives off very close to the two vessels above described a small branch which, passing through the gland, reaches the surface again on the left side and passes into the mantle. This will be easily seen (in injections with lard) on the left side of the gland.

At about the level of the upper lip, a small vessel is given off, passes to the anterior surface, and breaks up to supply the external labial palps and the upper lip (fig. 17, *A. l.*). The capillaries, or very small vessels, can be followed out on the palps if the injection is successfully carried out.

The main branch continues downward, still situated slightly nearer the right side of the animal, to enter the visceral mass, and branches are given off to the digestive gland. On the right side of the aorta a vessel arises which reaches the surface in the median line above the base of the foot, along the upper side of which it passes just beneath the epidermis, to supply the foot with blood (fig. 17, *A. p.*). This vessel gives off branches to the lower lip and inner palps, as indicated in the figure.

Returning to the main branch, this is continued by a smaller vessel which lies on the right side of the alimentary canal, and follows it in its course through the visceral mass, giving off small vessels to the ascending loop of the intestine and to the reproductive organs. There is another vessel of almost the same size which arises from the above, at about the level of the foot, and passing deeper into the visceral mass, bifurcates into two branches which pass along the left side of the descending loop of the intestine (fig. 14, *A. v.*).

The Posterior Aorta (fig. 14, *Ao. p.*) is a large vessel which leaves the ventricle below the intestine and on its right side. It runs for a short distance along the right ventro-lateral side of the rectum, and then gives rise to three vessels, the Rectal Artery (fig. 14, *A. r.*), which runs alongside the rectum, supplying it to the end, and two much larger vessels. One is the Posterior Pallial Artery (fig. 14, *A. p. p.*), the most important artery to the mantle, which turns upwards at an acute angle and runs in the roof of the pericardium towards the hinge line; it then passes to the posterior angle of the hinge and bifurcates, forming right and left Circumpallial (fig. 14, *A. c.*) arteries, which pass round the extreme margin of the mantle lobes and communicate eventually with the much smaller anterior pallial arteries.

The other large vessel arising from the posterior aorta is the Adductor Artery (fig. 14, *A. add.*). This leaves the aorta at a right angle, and plunges into the adductor muscle immediately in front of the deep cleft dividing the striped muscle from the unstriped. On entering the muscle, small vessels are given off from its posterior side, which pass out of the main bundle of striped muscle and, crossing the cleft, enter and supply the unstriped portion. The main artery, however, passes down towards the middle of the adductor, where it divides, sending branches in all directions. The figure shows the course taken in one of the specimens where the injection mass went very successfully, but probably here, as in other places, there is great variation in the smaller branches.

The VENOUS SYSTEM (fig. 18) consists largely of sinuses, and contrasts thereby with the fine arterial vessels. There are three main sinuses situated between the adductor muscle and its connective tissue sheath, which account for the large outflow of blood when the muscle is cut from a valve.

A large Dorsal Sinus (fig. 18, *S. D.*) is situated under the pericardium and digestive gland; anteriorly, this communicates on both sides with the renal organs. On the ventral side of the adductor, there are two sinuses, which extend from the cleft dividing the striped and unstriped portions of the muscle up to the renal organs. They are continued under these and the visceral mass, and communicate with one another. The main opening of these sinuses to the renal organ is at the dorsal end, and by slitting up the outer surface, the renal veins may be seen branching and becoming much smaller as they pass from the pericardial end towards the reno-genital opening (fig. 12, *Ro. r.*).

A large Hepatic vein (fig. 18, *V. h.*) on each side of the digestive gland, lying immediately under the epithelium, passes ventrally and slightly forwards to the anterior end of the renal organ, where it enters the dorsal sinus. Branches join it from the digestive gland and stomach.

A sinus-like plexus of vessels between the muscle and the visceral mass passes blood from the gonads and intestine to the sinuses communicating with the renal organs. The blood from the adductor passes along ill-defined paths in that muscle to enter these sinuses, thus completing the circuit.

The greater part of the blood from the visceral mass and alimentary canal passes by very conspicuous veins on the surface of the gonads (fig. 18, *V. e.*) to the sides of the renal organ, where they communicate with the numerous small vessels of the latter.

Thus all the blood is brought to the renal organs, with the exception of that which proceeds by the pallial arteries to the mantle. This will be considered later.

The blood returning to the heart leaves the renal organ by a series of fine vessels in the outer wall which open into a wide passage, the entrance to the afferent branchial vessel (fig. 16, *Br. aff.*). This soon contracts in size, and the vessel runs along the ctenidial axis proximal to the accompanying efferent vessel. It communicates with a vessel or cavity on each of the respiratory expansions of the principal filaments, but no connections with any of the other gill filaments can be seen.

The blood is brought from the gills, after aeration, to the heart, by means of the efferent branchial vessels, which, coming from the ctenidial axes, pass between the digestive gland and the adductor, and open into the narrow ends of the auricles, after receiving, at about the level of the dorsal extremity of the glandular part of the renal organ, the pallial vein (fig. 11, *V. pall.*), which brings back to the heart, directly, the blood from the mantle lobes.

The mantle lobes have an extremely large system of vessels (fig. 11), which are usually injected along with the arterial system. The Pallial Vein can be first traced at a point just within the circle of attachment of the pallial muscles, posteriorly (fig. 11). From this point it proceeds anteriorly, gradually approaching the adductor muscle on its way, until finally it reaches and opens into the efferent branchial vessels. On both sides, but principally on the ventral, it gives off a series of branches which divide and re-divide, ramifying in the thickness of the mantle and forming a complete network which abuts on the circle of pallial muscles, and is connected by a series of fine passages between these to the circumpallial arteries (fig. 11, *A. c.*) already described. The mantle lobes are thin, and comparatively little metabolism goes on there, especially when one considers the great area of blood spaces, and it must be assumed that the mantle lobes play the most important part in the respiration of the animal. The blood from the mantle reaches the heart without having passed through the renal organ, so that the heart contains mixed blood—completely aerated blood from the mantle, and probably incompletely aerated blood from the gills. This mixed blood will pass both to the pallial respiratory surface and to the body generally, from whence it is collected and taken to the renal organs, then to the gills, and so back to the heart.

NERVOUS SYSTEM.

The nervous system of Pecten is of the typical Lamellibranch type. The usual three pairs of ganglia—cerebral, pedal and visceral—are present, though much modified in shape and position. In addition to these, there are collections of nerve cells along certain nerves, in particular the circumpallial nerve (fig. 26, *N. c.*), which renders the latter almost a fourth ganglion, both structurally and functionally.

Cerebral ganglia. The pair of ganglia known as the cerebral, or better—the cerebro-pleural, representing the fused cerebral and pleural ganglia occurring in Nucula and Solenomya, are found best by pulling the lower lip dorsally and moving the labial palps aside, so as to lay bare the area between the lower lip and the foot. The ganglia will then be seen faintly through the overlying tissue, which must be removed carefully or they will be pulled away with it. They are situated a considerable distance below the mouth and oesophagus, and very close to the pedal ganglia. Each ganglion (fig. 27, *G. cb.*) shows indications of being bilobed, and this is further borne out by sections which show a distinct, though not a deep, division into two lobes. From the upper corner arises the cerebral commissure (figs. 26 and 27, *Com.*). This connects the two ganglia and passes dorsally over the oesophagus, but owing to the position of the cerebro-pedal ganglia it is a larger loop than is usually the case. From the outer sides of the ganglia, just below the depression dividing them, arise the anterior pallial nerves (figs. 27 and 26, *N. pa.*), and a smaller nerve which gives branches to the labial palps (fig. 27, *N. l.*).

The Anterior Pallial Nerve lies close to the cerebral commissure, and passes with it to the side of the oesophagus, embedded in the digestive gland. It rises to the surface and enters the mantle just dorsal to the upper lip where this joins the outer labial palp on each side, then, dividing into two branches, it passes to the margin of the mantle and joins the circumpallial nerve (fig. 26, *N. c.*) by several branches.

From the inner sides of the cerebro-pleural ganglia two delicate nerves (fig. 27, *N. ot.*) arise which pass deeper into the tissue and innervate two small bodies, which have a white appearance in dissections.

These are the otocysts (fig. 27, *Ot.*), and the Otocystic nerves in Pecten can thus be traced directly from the Cerebro-pleural ganglia. The lower ends of the cerebro-pleural ganglia gradually pass into the cerebro-visceral connectives (fig. 26, *Con. cv.*).

The Cerebro-pedal Connectives are very short nerves (fig. 27, *Con. cp.*), which arise about the middle of the inner sides of the cerebro-pleural ganglia and run towards each other and slightly towards the surface. They each bear a ganglionic swelling just before arriving at the pedal ganglia.

The Pedal Ganglia (*G. p.*) lie closely apposed to one another, so that the pedal commissure is so short that it is barely distinguishable. These ganglia are situated outside the foot, and are the nearest to the surface, so that probably they will be the first seen when looking for the cerebro-pleural. Both the cerebral and the pedal ganglia are pigmented yellow, and both have a similar structure, viz., a cortex of ganglion cells with processes passing into a core, made up of nerve fibres.

From the pedal ganglia, two pedal nerves (fig. 27, *N. p.*) pass directly into the foot, where they break up into numerous small branches, supplying the muscles.

The Visceral or Parieto-splanchnic ganglia are completely fused in Pecten to form one large and complicated mass (figs. 26, 28, *G. sp.*). It is the largest ganglion and gives rise to most of the nerves, and this can be accounted for by the fact that, compared with other Lamellibranchs, it is the posterior region of the body that is most developed in Pecten, the anterior with the anterior adductor having been suppressed and the foot reduced. Furthermore, the mantle, with its important muscles and sense organs, is innervated chiefly by the visceral ganglia.

The fused ganglia lie on the ventral surface of the adductor muscle, imbedded in a mass of connective tissue, and can be generally seen without any dissection (by reason of their yellowish brown colour), on the right side about 0·5 cm. from the last point of attachment of the visceral mass; that is, slightly postero-ventral to the opening of the right renal organ.

Its shape is very striking indeed (see fig. 28). There is a large central lobe, which is divided anteriorly by a transverse division into a light yellow posterior part, and an anterior portion which is more deeply pigmented yellow. This anterior darker part is sub-divided into two lobes. Laterally, the central lobe is connected by a depressed region with two crescent-shaped expansions or lateral lobes, practically without pigment. Thus there is a post-central lobe (fig. 28, *G. c. l.*)—unpigmented except in its anterior margin; two anterior lobes—darkly pigmented (*G. ant.*); and two lateral lobes—unpigmented (*G. lat.*).

These compound ganglia are connected with the cerebro-pleural ganglia by the cerebro-visceral connectives (fig. 28, *Con. c. v.*). These arise, as we have already seen, from the lower end of the cerebro-pleural, and at once take a course slightly inward and away from each other. That on the left side passes to the left of the rudimentary retractor muscle of the foot, and then lies along the base of the visceral mass at its sides, between it and the renal organs and closely apposed to the adductor muscle along the greater part of its course. The two connectives on reaching the visceral ganglion enter it just outside the anterior pigmented lobes, viz., by the anterior ends of the lateral lobes. The right visceral connective comes in rather at an angle, the left being nearer the median line.

Lying almost above the right connective, a little before it reaches the ganglion, and on the other side, a little to the left of the connective, are small pigmented bodies (*G. osp.*), which sections show to be ganglia made up of a cortex of ganglion cells with long processes passing into the centre, and with the outer ends drawn out into several fine fibres. From these osphradial ganglia, nerves pass up through the connective tissue to the epithelium directly above. Here they become connected with numerous sense cells, forming the Osphradium.

The nerves connecting these osphradial ganglia with the visceral, pass into the cerebro-visceral connectives and enter the ganglion with these nerves.

Two conspicuous nerves arise from the visceral ganglion close to the entrance of the cerebro-visceral connectives, but slightly posterior to these. They arise, also, at a slightly higher level than most of the nerves which pass to the mantle. These are the branchial nerves (fig. 28, *N. br.*); they pass out almost at right angles to the cerebro-visceral connectives, and just passing below the extremity of the renal organs, take up a position along the outer margins of the latter, where they are easily seen, being rather near the surface. This course is followed until the expanded end of the afferent branchial vessel is reached, when the nerves bend round and enter the ctenidial axis, along which they pass, gradually becoming more attenuated until the end of the lamellae is reached. The nerve lies alongside and above the afferent branchial vessel along its whole length (fig. 15, *N. br.*), sometimes nearer one side of the ctenidial axis than the other.

This nerve is well supplied with ganglion cells, which lie chiefly on the side nearer the gill filaments. The branchial nerve gives off laterally, from its ventral surface, small nerves, at frequent intervals along its whole length. These pass towards the base of the gill filaments at the sides of the afferent branchial vessel, until the two longitudinal ctenidial muscles are reached. They are continued between the muscles and the epidermis to a point about level with the middle of the muscle bundles, where they bear a considerable number of ganglion cells. From the ganglia thus formed, nerves arise, which extend in almost a continuous sheet to the bases of the filaments, down each of which a delicate branch passes. Thus, the gills have a very thorough nerve innervation, and are probably very sensitive, though specially differentiated sense cells have not been seen.

The Pallial System is supplied chiefly by the visceral ganglia. It is the most extensive in the body, and this is to be expected considering the array of sense organs with which the mantle is supplied, together with its important muscular system. It consists of a large nerve which runs parallel with the mantle edge, just interior to the pallial artery. This, the circumpallial nerve (fig. 26, *N. c.*) is physiologically a ganglion. It is well supplied with ganglion cells, and is thickest in the middle of its course. Anteriorly and posteriorly the nerves become very fine, and eventually reaching the hinge line the nerves of both valves become continuous, so that the circumpallial nerve is one continuous cord, which is much attenuated in two places at the hinge line, anterior and posterior, respectively. From the circumpallial nerve branches arise to innervate the eyes and tentacles (fig. 4, *N. c.*); the optic nerves will be described in the chapter on the eye. Each of the long extensible outer tentacles is supplied with a nerve which runs up to the centre and gives branches to the sense cells. The pallial muscles are also innervated by branches from the circumpallial nerve. The circumpallial nerve is connected with both the cerebro-pleural and visceral ganglia; with the former by the anterior pallial nerves (*N. pa.*) already described (figs. 16 and 18, *N. pall.*).

The pallial nerves from the visceral ganglion do not pursue a similar course on the right and left sides of the body. On the right, that is, the side on which the gill is attached to the mantle, the pallial nerves pass out as a large trunk very close to the branchial nerve, and run alongside this until the point is reached where the branchial nerve enters the gill lamellae.

Here they enter the mantle, and at once divide into branches which radiate out to the circumpallial nerve (fig. 3, *N. pall.*). The main branch, however, passes along in the mantle, after bending sharply, exactly in the line of attachment of the basal gill lamellae, and from this the various branches arise.

On the left side the distribution is somewhat different. The pallial nerves are not collected to form a large trunk, but radiate out directly from the ganglion over the surface of the adductor muscle until the mantle is reached; entering the mantle, they pass out, branching on the way, to the circumpallial nerve. In all probability these pallial nerves also innervate the pallial muscles. There are, in addition to the pallial nerves already described, certain nerves which leave the visceral ganglia from the posterior angles of the lateral lobes, and pass directly back over the surface of the adductor until they reach and enter the mantle opposite the terminal point of attachment of the rectum (fig. 28, *N. pp.*).

With regard to the histology of the visceral ganglion, the ganglion cells are, for the most part, grouped over the surface forming the cortex. The anterior central lobes are almost entirely composed of ganglion cells, which also abound on the central part of the dorsal surface (that is, the surface against the adductor muscle). The main part of the ganglion is made up of fibres, amidst which can be seen a very definite transverse series; probably the representative of the visceral commissure.

SENSE ORGANS.

Pecten is unusually well supplied with sensory structures, certain of which, the pallial eyes, attain a high degree of specialisation, and are a remarkable feature of the animal.

The sense organs are of five kinds, the first three, and probably the fourth, of which are common to the Lamellibranchiata, and do not differ to any great extent in the various genera. They are:—(*a*) Sensory cells in the epidermal layer; (*b*) a pair of otocysts; (*c*) a pair of osphradia; (*d*) an abdominal sense organ; (*e*) a series of highly-developed eyes.

(*a*) THE SENSORY EPITHELIAL CELLS.—These, the "Pinselzellen" of Flemming (**30**), are to be found scattered all over the epidermis, but are present in greatest numbers on the long, extensible tentacles of the mantle edge, where they occur between two "Stützzellen," which according to Rawitz have a common membranous covering. They are most abundant near the apices, and render each of these tentacles a most important tactile organ. This view is confirmed when the animal is observed living, and the greatly extended tentacles can be seen moving slowly to and fro in the water. A very slight motion in the water appears to be stimulus enough for a sudden retraction.

These sense cells are also present on the mantle edge proper, in the epithelium covering the adductor muscle in the neighbourhood of the visceral ganglia and osphradia, on the sides of the gill axis and in the outer epithelium of the rectum near the end of the free portion.

In shape, these sensory cells differ but little from the ordinary epithelial cells, which act as supporting cells around them. In many cases, however, they are very narrow, with the nucleus situated about the middle of their length. The narrow cells have the end towards the surface of the epithelium swollen out into a disc, which is just as broad as the ends of the other epithelial cells around. Another feature is that the sense cells stain more intensely when a nerve stain is used. The cells are provided with a bundle of extremely long cilia, as long, or longer, than the cells themselves. These cilia are quite characteristic structures, and much longer than those of ordinary epithelium. The margin of the sense cells shows a distinct striation vertical to the surface, as if the sense hairs or cilia were produced into the cell, and this striation can often be observed, though less distinctly (still deeper in the cell), as a series of lines converging towards the nucleus. The base of the cell is connected with the nerve fibres, ramifying under the epidermal layer and in connection with the deeper lying nerves, one of which runs up the centre of each of the extensible sensory tentacles. These cells are probably olfactory as well as tactile in function.

(*b*) THE OTOCYSTS. A pair of Otocysts (fig. 27, *ot.*) are present in both *P. maximus* and *P. opercularis*. They are situated quite external to the foot, embedded in the visceral mass amidst the connective tissue of the digestive gland: and lie beneath the cerebral and pedal ganglia and connectives, that is, on the side turned away from the surface of the body, and somewhat between the ganglia.

They can be seen in dissections as two minute delicate white bodies, if the connective tissue above the cerebral and pedal ganglia is carefully removed, and are perfectly spherical in shape, with a diameter of 0·17 mm.

The position of the otocysts outside the foot is interesting, as the pedal ganglia are also completely outside the foot in Pecten. There can, however, be no question here of the nerve innervation, for the nerves can be traced directly out from the cerebral ganglia without any connection with the cerebro-pedal connectives, thus rendering further proof to the theory that the otocysts are always innervated by the cerebral ganglia, even when they are connected with the cerebro-pedal connective and lie in close proximity to the pedal ganglia. The nerves enter the otocysts on the sides facing the cerebral ganglia, and are thus quite short. The otocysts in both *P. opercularis* and *P. maximus* are spherical closed sacs, the internal cavity of which is bounded by a layer of sense cells. In this cavity there is situated an otolith. This appears in *P. opercularis* as a large ball, formed of small crystals of irregular shape, as if a heap of fine detritus had been heaped together. The otolith thus formed fills almost completely the cavity of the otocyst. In *P. maximus,* I have only found some larger and more scattered crystals (otoconia) in the otocyst. In the adults of both species examined, the otocyst has no duct connecting the cavity with the external world.

THE OSPHRADIA.—These paired sensory structures, named by their discoverer, Spengel (**38**), organs of smell, and which are of general occurrence in Mollusca, are not highly developed in Pecten. They cannot be detected without the aid of microscopic sections, and though pigment granules are then seen to be present to a small extent in the cells, they are not frequent enough to give any conspicuous colour, and the organs differ greatly from the very obvious pigmented osphradia of many molluscs. Two small ganglia, the osphradial ganglia, have already been described in the section on the nervous system. They lie in close proximity to the visceral ganglion, and nerves pass upwards from the ganglion cells forming these two spherical ganglia to the surface epithelium, almost directly above, where there is a small prominent area of elongated epithelium forming the osphradium. If a piece of the adductor muscle is removed so that it bears on its surface the visceral ganglia and overlying connective tissue and epithelium, and sections are cut at right angles to the surface, the osphradial ganglia and their connections with the osphradia can be easily followed. The epithelial cells of the osphradium increase in height until they are about three times that of the adjoining ordinary epithelium. The cells forming the organ bear no cilia, though these occur on the ordinary adjacent epithelial cells, but there is a prominent cuticle present. The nucleus is large and almost round, and small pigment granules occur (though in small numbers) in the cytoplasm. Underlying the osphradia are nerve cells connected with the innervating nerves from the ganglia, and from these, numerous fibrils arise and pass through the connective tissue basal membrane, until, branching still further, they pass between the supporting epithelial cells to the surface (text-fig. 3).

THE ABDOMINAL SENSE ORGAN was described first by Thiele in a species of *Arca* in 1887 (**39**), and List in 1902 (**6**) described the structure in detail in the Mytilidae. In *Pecten maximus* it is well developed but is unpaired.

The microscopic structure is almost identical with that in Mytilus, and probably this organ occurs generally in the lamellibranchia. It is a slight uncoloured thickening situated on a connective tissue "flap" which passes from the adductor to the right mantle lobe, just above the last point of attachment of the rectum to the muscle. The free edge of this thin flap is directed towards the hinge line.

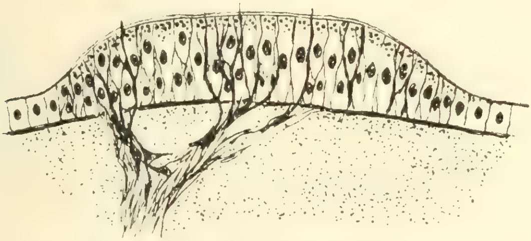

FIG. 3. Section through Osphradium. × 450.

If transverse sections are made through the ridge, the striking microscopic structure of this organ makes it at once obvious. It appears (see fig. 4) as a hillock of sense cells extending on both sides of the edge of the connective tissue flap, and much longer than it is thick. It is rendered very evident because firstly the cells composing it are many times higher than the ordinary epithelium and the junction is very distinct, and secondly because the sense hillock bears a thick covering of extremely long cilia or fibrils, which are themselves several times the length of ordinary epithelial cells and occur nowhere else on the body. The sensory epithelium rests on a basal connective tissue membrane which is pierced by nerves, or rather by nerve fibrils, which proceed from the visceral ganglion and pass directly over the adductor under its connective tissue sheath. In transverse sections stained with haematein the epithelium stains very deeply, and many nuclei are apparent which appear to lie at all levels with the exception of a narrow zone bounding the free surface of the cells.

The nerve fibrils break up into finer processes amongst the cells, and form a very complex network around them. Many of the nuclei appear to belong to the nerve fibres, whilst others much rounder and lighter staining probably belong simply to supporting cells. The nerve fibrils can be traced from their nuclei to the edge of the hillock, where they are continued free as the long cilia, so that these are in reality the terminations of primitive neuro-fibrillae.

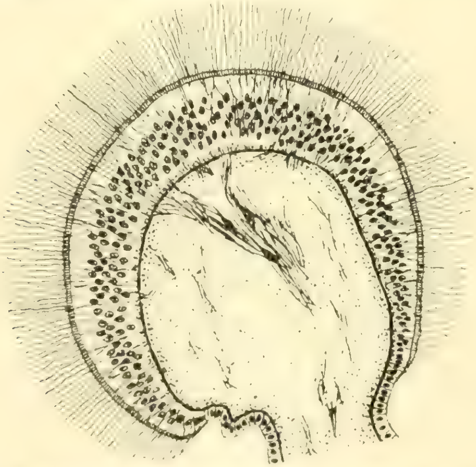

Fig. 1. Section through abdominal sense-organ. × 300.

There is, in addition to the covering of long cilia, another much narrower "seam" lying at the bottom of the cilia, and in fact having the appearance of a very thick cuticle formed of a number of delicate parallel rods. It has rather the appearance of another short layer of stiff cilia. These rods can also be traced for a short distance within the cells.

With regard to the function of this well-developed organ, it is difficult to see that it can be any other than a water-testing, either smell or taste organ, yet this sense is generally ascribed to the osphradia, and it is difficult to understand the presence of two organs doing the same work, situated very close to one another, and yet having a different structure.

The histological structure is remarkably like that of the "Seitenorgane" described by Eisig (**43**) in the Capitellidae, and Thiele himself supposes that the function, like that of these organs and the lateral line of fishes, is the perception of vibrations in the water, though no experimental evidence is put forward.

THE EYES.—No organs of Pecten, nor of the Lamellibranchs in general, have given rise to more discussion with regard to details of structure than the eyes; and as one would expect, these remarkable organs, which are so prominent, glittering like minute diamonds set amidst a forest of tentacles, attracted the attention of early naturalists. They were first described by Poli, as far back as 1795. The first fundamental work was that by Hensen in 1865 (**31**), and since then the most important papers are those by Hickson in 1880 (**33**), Carrière 1885 (**29**), Patten 1886 (**35**), and Rawitz in 1888 (**36**). The structure of the retina was, however, still very uncertain, and this has been the chief feature of the works of Schreiner 1896 (**37**), Hesse 1900 and 1907 (**32**), and Hyde 1903 (**34**), bringing the matter up to date. The difficulty of making satisfactory preparations, and the frequency of artifacts caused by fixation and further treatment, has been the cause of much confusion.

The mantle, as previously described, has a margin bearing the characteristic lamellibranch structures (see fig. 4). There are three folds, on the outer of which are borne tentacles, and on the median and smaller are situated the eyes (fig. 4, *E.*), on short stalks which resemble the basal portions of the ordinary tentacles. Many workers have noticed this similarity, which, together with the course of the nerve fibres, has led them to the conclusion that these are homologous organs modified for different functions. The Pecten eye is an inverted eye like those of Planarians and Vertebrates, and resembles the latter in some respects. It is derived from both ectoderm and mesoderm, the lens being formed from the latter. The number of eyes varies considerably in the different species, and there is further a difference in the number on the two mantle lobes.

In *Pecten maximus* the numbers average about 35 on the left (flat) side and as few as ten, separated by long intervals, on the right (convex) side. In *Pecten opercularis* the numbers are more equal, the following being some series:—right, 37, 35, 41, 51; left, 52, 51, 56, 61; but it will be seen they still are more numerous on the left than on the right, though the left valve of *Pecten maximus* is the flat one, whereas the right valve is the flatter of the two in *Pecten opercularis*.

Patten (**35**) observed that *P. jacobaeus* always lay on its right valve, that is the convex, and if turned over it soon righted itself.

Pecten maximus, which like *P. jacobaeus* has very unequal valves, is always to be found lying on the right convex valve which suggests that the greater development of eyes is always on the flat upper valve. This is supported by the condition in *P. opercularis*, where little difference can be detected between the valves, and the number of eyes is more alike than in *P. maximus*. One might at first expect that the eyes looking up toward the light would be the better developed, but the eyes on the left upper valve are the more numerous, are larger and situated on longer stalks in *P. maximus*. This may be a result of the asymmetry of the animal, and I have observed that the left mantle lobe is frequently extended so far out that it overlaps the shell edge, and the eyes are directed horizontally out, or even upwards, in place of downwards towards the ground, as has sometimes been stated. The eyes vary in size considerably. There is a group of large eyes anteriorly and posteriorly on each mantle lobe.

In *P. opercularis* there are about five eyes in each such group, and separated by an interval from these we have a series of eyes in the ventral margin. Those nearest the interval are the smallest, and the largest are to be found mid-ventrally. I do not find, however, the regular arrangement of large and small eyes described by Patten (**35**). Neither have I been able to find in *P. opercularis* any eyes "the pupils of which are entirely covered with pigment" (Patten, **35**).

The eye stalk (fig. 29, *E. st.*) which supports the eyes is a short column, and is retractile, but one does not observe the eyes being turned in different directions as is the case with the tentacles. The lower part of this eye stalk is bounded by unpigmented epithelium, but as the eye is approached, the amount of pigment granules in the epithelium cells increases until the whole cell is almost filled. The pigment is of a dark brown or blackish colour. In sections it will be seen that the epithelium is composed of columnar cells, which are lowest at the base but become taller as one approaches the cornea (*Cor.*), which is a continuation of the same layer over the surface of the eye.

The pigment granules are thickest at the bases of the cells, the nuclei of which are generally situated in the upper part. The pigmented cells are not equally distributed, but are most numerous and extend nearest to the base of the eye stalk, on the upper side which is turned towards the light (fig. 29, on left side).

The name **iris** has been given (fig. 29, *I.*) to the zone bounding the cornea where most pigment is present. The cells of the iris become rapidly less tall, the nucleus becomes more central, and then suddenly all pigment is lost, and they pass into the cubical, transparent cells of the cornea (fig. 29, *Cor.*). A thin layer of cuticle covers the epithelial cells of the eye stalk, the iris and the cornea.

The function of the iris seems to be, like that of the pigmented sides of the eye vesicle and stalk, to prevent lateral rays of light penetrating to the retina.

The cells of the cornea were discovered by Patten (**35**) to be pentagonal or hexagonal in surface view, hour-glass shaped in section, quite free from pigment, and to have a curious interlocking or notched appearance on the edges, so as to give the cornea a much firmer and more rigid structure as a membrane. This appearance was described by Schreiner (**37**) as being due to intercellular substance and to fixation alone.

From transverse and longitudinal sections through these cells fixed in Mann's Fluid, Flemming's Reagent and Osmic Acid, I am of opinion that they do possess processes on all sides which probably connect them together, as in the so-called "Prickle Epithelium." This occurs also in the epidermal cells of the eye stalk (fig. 35).

The connective tissue which makes up the rest of the eye stalk is a continuation of the same from the mantle, and is similar in structure. There are numerous lacunae with blood corpuscles, and the rest consists of almost structureless, homogeneous connective tissue with scattered nuclei and a few muscle fibres (fig. 29, *Op. m.*), which later are present in considerable quantity in the layer immediately below the epidermis, and probably cause the slight movements of the eye. I have seen no trace of Patten's long striated muscle cells; but the muscle fibres when contracted may be thrown into a series of short waves, which possibly produced the striated effect.

The connective tissue of the eye stalk is continued up to form the sides of the optic vesicle, and is actually prolonged under the cornea as a structureless layer with a few nuclei—the pseudo-cornea (fig. 29, *Cor. ps.*) of Patten (**35**).

The muscle fibres extend up laterally as far as the edge of the iris, and end quite suddenly with an upward curve, as if attached to the last cells of the pigmented iris. This is the region that Patten has termed the Ciliaris.

Scattered ganglion cells are also occasionally to be seen in the connective tissue of the stalk. They are probably connected by nerve fibrils with the nerves of the eye.

Lying in the optic vesicle, against the pseudo-cornea, is the Lens (fig. 29, *L.*), which Patten has figured and described correctly (**35**). It is biconvex, but the dome-shaped surface towards the retina is very much more convex than the corneal surface. The lens is composed of large cells, irregular in shape, but more or less rectangular in the centre. They have distinct walls, and granular contents which stain somewhat deeply with eosin. The nucleus always lies to one side of the cell, so that in thin sections some of the cells appear to be without a nucleus. Fibrils are of frequent occurrence in these cells, and Hesse (**32**) states that they have a radial arrangement from the centrosomes to the periphery.

The cells are smaller at the circumference of the lens, and the cells bounding the corneal and retinal surfaces, especially the latter, are elongated and flattened. It is probable, owing to the layers of the flattened cells with fibrils and prominent walls that the appearance of a membrane, called by Patten the suspensory ligament, arose. No definite membrane can be seen by Schreiner or myself.

The lens lies suspended in a space which has been termed a blood sinus, as blood corpuscles are occasionally found. This space, which is situated between the retina and the lens, like the chamber in the vertebrate eye containing the "vitreous humour," does not appear to have any connection with the lacunae of the eye stalk. I have found blood corpuscles only present in very few out of a great many sections, and these were probably abnormal occurrences due to fixation only, and the space cannot, therefore, be looked upon as a blood sinus.

The Septum.—The portion of the optic vesicle containing the retina is separated from the lens chamber by a membrane which runs completely across the eye. This is the Septal Membrane (fig. 29, *Sep.*). Commonly the retinal surface of the lens lies against it. Patten, however, considers it a support for the lens to which it is actually attached, and, further, that it plays the part of an elastic cushion elevating the lens when it has been pulled in by contraction of muscle fibres.

Owing to the retina being pulled away from its underlying layers in sections, the septum comes perhaps to touch the lens, but in the natural conditions the lens and septum are not attached, and the latter can thus not act as an elevator. Moreover, the whole appearance of the eye and its reactions to stimuli render it extremely improbable that it possesses any means of accommodation or focussing.

The septum in the adult appears structureless, thickest in the middle, where it is perforated by the outer branch of the optic nerve. At this place the septum has the appearance of being formed of two membranes placed together, and which are here slightly separated. the nerve passes intact over the septum to the middle, where its several fibrils penetrate the membrane, diverging at the same time in all directions to make their connections with the outer layer of retinal cells. The peripheral edge of the septum appears to be a direct continuation of the sclerotica (fig. 29, *Scl.*).

Retina.—The Retina and its two underlying layers have received, at different times, varying names. I have adopted in the main those of Hesse, with some alterations; the chief synonyms will be referred to in the text. In sections the retina appears as a thick band lining the inner wall of the optic vesicle, but separated from it by two other concentric layers—the argentea and the tapetum (fig. 29, *Arg.* and *T.*). The retina further resembles in a remarkable way that of the vertebrate eye, in the fact that the light rays must pass through it to the argentea, and then the nervous reactions aroused pass back again through the various elements to the optic nerves which innervate the retina on its distal surface. This arrangement is only approached outside the vertebrates in the Planaria (Hesse, **32**), and there the structure is much simpler. In most figures a space is shown between the retina and the argentea. This appearance, however, is due to contraction on fixing, and normally retina, argentea and tapetum are in contact. The retina has been the source of all the disagreement with regard to the structure of the Pecten eye, and I have endeavoured to examine the various views held and compare them with the appearances of my own preparations; but a complete elucidation has not yet been arrived at. The retina can be divided into three main layers, viz.:—

(*a*) An outer layer lying against the septum, and made up of the Distal Cell layer (fig. 29, *D. c. l.*) and Outer Interstitial Cells (fig. 30, *In. c. o.*). This is Patten's outer ganglionic layer and the Ganglienzellenschicht of Rawitz (**36**).

(*b*) The layer of Rod Cells (Retinophorae—Stäbchenzellen (fig. 29, *R. C.*).

(*c*) The layer of Rods (Stäbchen) (fig. 29, *R.*).

The cells of the inner ganglionic layer of Patten, corresponding to the Zwischenzellen of Hesse, and what I shall call the inner interstitial cells, are to be found between the rod cells (fig. 30, *I. c. i.*).

Rod Cells.—With regard to the minute histology of these structures much confusion exists. They form the most conspicuous portion of the retina in transverse sections, and are prominent as a layer of columnar cells, the basal proximal ends of which are continued as the rods forming another well-defined layer of the retina.

The rod cell layer is thus the middle layer of the retina, lying between the layer of rods and the distal layer of cells, to be considered below. The rod cells are of considerable length, and decrease gradually in thickness towards the periphery of the retina until, indistinguishable from nerves, they become connected with the fibres of the inner branch of the optic nerve (fig. 29, *Op. n. i.*) which pass down outside the optic vesicle on all sides and unite to form the nerve branch under the eye. In order to study the details of a rod cell, sections must be cut in the plane of the retina and at right angles to the long axis of the eye-stalk. An examination of teased preparations is also necessary in addition to the sections.

The rod cell increases gradually in diameter from a mere thread at the back of the retina to the typical columnar region. At about a fourth of its length is a slight varicosity, and a short distance further and nearer the basal end the nucleus causes a rapid increase in the diameter (fig. 30, *R. C. n.*, and fig. 29, *R. C. n.*). The nuclei of the rod cells are to be found in longitudinal sections through the eye, in a cluster not far from the sides of the retina (fig. 29, *R. C. n.*) and before the point is reached where the cells curve almost at right angles to form the basal portions, which like a series of columns lie with their long axes in a proximal-distal direction.

Another series of nuclei is generally conspicuous (fig. 30, *C. i.*), but, as first shown by Patten (**35**), these do not belong to the rod cells, but belong to cells lying between them (inner interstitial cells). The rod cells all terminate at the same level, or rather pass directly into their continuations—the rods. At the line of junction of these two elements there are traces of a delicate membrane extending across the retina, called by Schreiner (**37**) the outer sieve membrane (fig. 30, *S. m. o.*). This is perforated by the rods, and does not, as Patten stated (terminal membrane), separate the rod cells from the rods, that is, form the actual base of the rod cells. Each rod cell is connected with a rod, the one being a continuation of the other, the line of division being marked by the outer sieve membrane outside the cell, and internally by a difference in cell structure. Like Schreiner, I have seen no vacuole described by Patten as existing at the base of the rod cells.

The Rods (fig. 30, *R.*) are difficult to preserve in good condition, but absolute alcohol sublimate gives good results, and sometimes Flemming, though with large *Pecten maximus* eyes the latter probably does not penetrate quickly enough. They are cone-shaped bodies, longest in the centre of the retina and decreasing slightly in size towards the periphery. The basal portions of the rods are separated from each other by, and rest on, a substance staining rather darkly with Iron-Haematoxylin (fig. 30, *S. m. i.*) which separates them from the underlying argentea. There has been some disagreement as to whether this is a secretion of the argentea or an artifact. It is certainly not the latter, nor have we to do with single rod mantles as stated by Rawitz (**36**). It is simply a homogeneous mass in which the rods are imbedded, and I propose the name Basement Membrane instead of Schreiner's Inner Sieve Membrane, owing to the difference from the outer sieve membrane. Hesse (**32**) has calculated in *Pecten jacobaeus* there were present 24,000—27,500 rods to the sq. mm. That is about 2,400 rods as the average for a medium-sized eye.

The internal structure of these elements, both rods and rod cells, has caused much confusion. The rod cells have rather more compact protoplasm than the rods, which appears in sections to be condensed rather in the middle (fig. 32). In transverse section the rod cells appear rather irregular in shape—some circular, others rectangular or triangular; the appearance, in short, that cylindrical columns might have in consequence of the pressure of adjoining cells. The rods are not so irregular in shape, and the cell contents are not so conspicuous, but running down through the middle is a well-defined axial fibre (fig. 32, *Ax. f.*). This can be seen excellently after fixation in Flemming and staining with Haematoxylin, and is distinct, both in transverse and longitudinal sections. It was, however, best followed after treatment by Apathy's "Nachvergoldung Method" or by the same author's Haematein IA. This fibre can be seen distinctly in all rods extending from the base of the rod cell to the base of the rod (fig. 30, *Ax. f.*) Patten (**35**) described it as dividing at the base into two branches, which became connected with other nerve twigs outside the rod. This is not the case, it passes directly to the base of each rod, where it terminates. Both Patten (**35**) and Rawitz (**36**) have followed this structure through the rod cells. Rawitz stated in addition that there was a fine canal running through the middle of the rod cell, in which lay the fibre. Schreiner (**37**), after making a careful series of preparations, came to the conclusion that there was no axial fibre in the rod cell, and that the appearance of one was due to the contours of adjacent cells, or an optical effect formed owing to the rod cells being slightly angular in transverse section and not perfectly cylindrical. Hesse (**32**) acknowledges that it is often extremely difficult to find the fibre in the rod cells, even when it is perfectly obvious in the rods, but confirms Patten, and states that in *Pecten aratus* the fibre is easily followed in the rod cells.

The eye of *Pecten maximus* is not suited for this histological work, but transverse sections made through the retina (figs. 32 and 33), and cutting both rods and rod cells, show how distinctly the fibre is to be seen in the former whereas it is absent in the latter, and here both rods and rod cells have been subjected to exactly the same conditions of fixation and staining. In the Gold Chloride preparations, however, the fibre was seen in some rod cells to extend very slightly above the base, and not to end abruptly but rather to thin out. Apathy's (**27**) and Bethe's (**28**) work on the nervous system has thrown much light on the structure, and if we regard the nerve cell as simply a cable, the conducting wires of which are the neural fibrillae and the perifibrillar substance the protective and insulating material, we can apply this to the rod cells. The axial fibre in the rods is a nerve fibril lying in its nerve cell. It is so obvious because it is in all probability the product of the fusion or very close apposition of several primitive fibrillae.

Now, it is very difficult to consider this ending abruptly at the base of the rod cell, especially if it be regarded as the conducting element. It is also certain that it is always seen only with great difficulty in the rod cells, and I could not demonstrate its appearance in the eyes of *P. maximus.*

Hesse (**32**) states that in some cases he could see several fibrillae in the rod cell, and in any case the neuro fibril was always thinner there.

Furthermore, the appearance in transverse sections shows that the cell contents which seem equally distributed in the rod cells (fig. 33) are condensed, and with the prominent axial fibril run down the centre of the rods (fig. 32). Bethe (**28**), in his work on the nerve elements of *Carcinus*, states that after using Toluidin and Methylene blue methods the primitive fibrillae appear with different intensity, and says there is in places a more or less stronger apposition of the "Elementar fibrillen" which form the primitive fibrillae, and the darker stained primitive fibrillae are due to the union of more "Elementar fibrillen."

I believe, therefore, that in the rod cells there are a number of very thin primitive fibrillae which at the periphery of the retina become connected with the neuro fibrillae of the optic nerve. These are only with difficulty to be made out, but have been seen on some occasions, and also by Hesse and Schneider (**44**). At the base of the rod cell there is, however, a fusion or an apposition of these neuro fibrillae, and the resultant obvious axial fibre of the rods is produced. I have reproduced this somewhat diagrammatically in fig. 30.

Hyde (**34**) has published an account of the structure of the Pecten eye which differs considerably from all the previous accounts. Unfortunately, no transverse sections are figured, and I have failed to find the structures described in my sections, which agree with those of Hesse. Hyde describes the rod cells as being simply supporting, and not visual sensory cells, and, further, that it is the inner interstitial cells (which lie between the rod cells) that are continuous with the axial fibril of the rods on the one hand and the optic nerve on the other. The rods, however, as above stated, are undoubtedly continuations of the rod cells, and though Methylene blue may be perfect for nerve fibrils, it cannot alter this fact, which has been observed by all observers in teased preparations and sections. Any continuations of the inner interstitial cells penetrating the outer sieve membrane will lie, therefore, between the rods, just as the former themselves lie between the rod cells.

In addition to the normal rod cells with their rods which have been considered above, there is a peripheral region in which rod cells are present which differ slightly in structure from the others and do not bear rods at their bases (fig. 29, *R. C. p.*); these were called Pseudoretinophorae by Patten. They are regarded by Hensen as young rod cells, and Schreiner states that he found them to be more numerous in young specimens than in the adult.

So far we have only considered the rod cells and the rods. In addition to these, the retina is made up of a number of other cells which form a definite band between the rod cells and the septum, and another layer, previously mentioned (inner interstitial cells), which lie between the rod cells. Patten classified all those between the septum and the rod cell layer as belonging to the outer ganglionic layer, and the others to the inner ganglionic layer. Rawitz also classified all these cells together as ganglion cells, and later Schreiner describes the outer ganglionic layer as being four cells deep in its thickest region. Hesse first showed the incorrectness of these statements. In the first place, the cells are of at least two different forms, and cannot all be classified as ganglion cells, and the so-called outer ganglionic layer of Patten and others is really a complex which must be broken up.

There is a distinct distal cell layer (fig. 29, *D. c. l.*), one cell deep only, extending across the retina against the septum. Between these cells and underneath this layer are a number of irregularly placed cells, which agree in many ways with those between the rod cells. Since their function is not known, it is best to drop the term ganglion cells, and to call them all interstitial cells; and so there are the two groups outer interstitial cells (fig. 30, *In. c. o.*) underlying and partially penetrating the distal cell layer, and inner interstitial cells (*In. c. i.*) between the rod cells.

The Distal Cell Layer is a very regular layer of roughly triangular cells, the base of which is turned towards the septum. The septal surface of these cells is drawn out into numerous fine processes almost like cilia, which reach up to the septum, so that in sections across the retina a cilia-like border appears between the septum and the retinal cells. They appear almost like numerous nerve fibrils in connection with the optic nerve, and make the task of following the real nerve fibrils in this region very difficult. The apex of the cell is drawn out and, according to Schreiner, becomes dendritic, sending delicate fibrils ramifying between the interstitial cells and rod cells. In the gold preparations these nerve fibrils appeared as a very complete network, and their number adds again to the task of examining their connections.

Schreiner stated that the epithelial distal cells were in direct connection with the outer optic nerve by means of one of the cilia-like fibres, which he illustrated as coming from the middle of the septal surfaces.

Hesse, in 1900 (**32**), could not see any connection between the fibres of the optic nerve and the distal cells, but traced the nerve fibres between them to connections with the interstitial cells, which he regarded then as sense cells but not ganglion cells. In a later paper, however (1907), after a study of the very early stages, he shows that the optic nerve is already connected with distal cells before the interstitial cells are in existence. According to him, the nerve fibrils of the outer optic nerve, after boring through the septum, pass between the distal cells and connect to the sides, and not the middle of the septal surface as stated by Schreiner. The attachment of the outer optic nerve to the distal cells is practically certain, but there is still great doubt about the interstitial cells, and though I could trace their processes to the cilia-like border, there could be no certainty of connections in the confusing mass of fibres.

The Interstitial Cells are irregular in shape and drawn out into fine branching processes. The outer interstitial cells bear processes which pass between the distal cells to the retina surface. The inner interstitial cells are very much flattened, and lie in such close proximity, wrapping as it were round the rod cells, that their nuclei were first taken for the nuclei of these. The cells are rather small, very little larger than the prominent nucleus, and, in addition to processes extending amongst the rod cells, one from each cell penetrates the sieve membrane and lies between the rods.

The nuclei of the interstitial cells stain very darkly with Haematein, and quite differently to the nuclei of the rod and distal cells. Hesse, Patten and Schreiner have regarded the interstitial cells as sense cells. Schneider, however, on the ground of structure, the nucleus, and the failure to prove a connection with nerve fibres, considers them to be supporting cells. Until the difficulties of following their fine fibrils are overcome, it will be better to call them interstitial cells, which leaves the question of function open.

Argentea Underlying the retina is this layer (fig. 29, *Arg.*, fig. 34), made up of refractive granules. This is the layer which gives the eye the beautiful metallic appearance, aided, of course, by the pigment layer—the tapetum. Patten, by painting several white lines on the base of the objective and focussing down on a large eye removed from the mantle, was able to see the image formed in the eye. The different layers could be followed, and the image was seen to be most distinct just before reaching the tapetum and argentea, so that the lens and argentea together act as a true optic lens and mirror, and form an image just where the rods are placed to receive it.

The argentea (which does not generally stain in sections), is made up of several laminae, and longitudinal sections have the appearance of a series of layers of small iridescent scales. If the argentea be looked at from the surface (fig. 34), it is seen that the layers are formed of numerous very small and almost square plates. These are arranged regularly together in one plane, so that the square face of each plate is in the plane of the argentea, and the edges only are seen in longitudinal sections. The argentea is thickest in the centre, where the laminae are most numerous, and towards the sides it thins out. There are no nuclei in this layer.

Tapetum. Below the argentea is this red pigment layer (fig. 29, *Tap.*). It is of considerable thickness in the centre, but, like the argentea, decreases towards the periphery, and terminates at the point where the retina comes in connection with the sides of the optic vesicle. The tapetum is composed of large irregular cells arranged rather irregularly in two layers, and in many cases the margins are difficult to define owing to the dense pigment contained in them. The cells contain each a nucleus, often obscured by the pigment, which is present in the form of rather large granules, in shape something like those found in the digestive gland cells, but of quite a different colour—a dark brown-red. The pigment granules are much larger than those found in the cells of the iris.

There only remains to be described the inner wall of the eye vesicle against which the tapetum rests. This is known as the sclerotica (fig. 29, *Scl.*), and is a differentiation of the connective tissue of the stalk, which becomes tough and hyaline and stains rather more deeply than the surrounding tissue. It passes into the septal membrane at the edge of the retina, so that septal membrane and sclerotica together form a closed vesicle in which is situated retina, argentea and tapetum, the whole being known as the ommateal sac.

Optic Nerves. The eyes are innervated by optic nerves, which arise from the circumpallial nerve and pass through the centre of the eye stalk (fig. 29, *Op. n.*) until the eye vesicle is almost reached. Here the nerve divides into two branches, one of which, the inner nerve (*Op. n. i.*), continues its course until immediately below the sclerotica, where it breaks up into many bundles of nerves, which radiate from this point and ascend on all sides of the eye vesicle to reach the periphery of the retina where they are continuous with the rod cells. The other branch, the outer nerve (fig. 29, *Op. n. o.*), passes distally on the shell side of the eye stalk, and, as already described, passes over the surface of the septal membrane, perforates it, and its fibres unite with the distal cells.

As to the function of the eyes in Pecten, Patten, apparently in order to surmount the difficulty of an animal having more than two eyes of such complexity, has advanced the theory that they are organs for the reception of solar energy, which is then transmitted along the optic nerves to centres where it is used in the building up of protoplasmic compounds, or in metabolism generally. Leaving aside the physiological objections to such an idea, which has been severely criticised by more recent workers, it will be seen that Patten assumes the structures are such as would be evolved for the purpose of receiving solar energy, the rays of which are concentrated by the lens.

A lens, however, cannot increase the solar energy falling upon its surface, it can only cause the rays to fall upon a smaller area of the retina. In a review of Patten's paper in the Q. J. M. S. for 1887, it was pointed out that "a naked epidermic surface of area equal to that of the lens would present a perfect instrument for the absorption of solar energy."

Observations carried out on Pectens living in the tanks at the Port Erin Biological Station have shown that they are very sensitive both to light and to sound waves. If a dark object is moved in front of a Pecten so that the shadow falls over the eyes, a rapid closing of the valves immediately follows. A sudden increase in the illumination apparently produces no effect. The flashing of the light from a bright lantern on the animals, which have the valves open and the tentacles extended in the darkness of the aquarium at night, causes no retraction or closure of the valves.

It is obvious that with a lens forming an image on a retina of such a type as is present here, the several eyes will have but a limited area from which rays can be focussed on the receptive surface. I have never observed the eyes of Pecten being moved in various directions, they can only form an image of some object directly in front of them. This will account for the need of such a number of eyes, if they are to be of real use as visual organs.

EXCRETORY SYSTEM.

The most important renal excretory organs are the paired glands (fig. 1, *R. o.*) lying at the sides of the visceral mass, and sometimes known as nephridia. They were formerly termed the organs of Bojanus, after their discoverer, who first described them in 1819.

Morphologically, they are like nephridia only in as far as they open on the one hand to the exterior and on the other hand into the pericardium—the remains of the coelom. But, since they are out-growths from the coelom, they are true coelomoducts.

In Pecten, they are elongated pouches of a light to dark brown colour. They are attached to the anterior surface of the adductor muscle, on each side of the visceral mass, and lie between the latter and the ctenidia, extending over the muscle for about 90° from the region of the digestive gland to near the last point of attachment of the visceral mass.

They are slightly asymmetrical, the left being the larger of the two, and this difference is correlated with the position of the visceral mass. The organ lies directly on the adductor, the glandular walls being separated from it by connective tissue. The outer wall of the organ of Bojanus is formed by a direct continuation of the epithelium of the visceral mass over it, on its way to form the epidermis over the gill axis. The coelomoducts are flattened sacs, increasing in width from their upper ends and widest at a point where the afferent branchial vessel leaves them. From this point they narrow rapidly to their distal end, which is pointed and lies close to the visceral mass. They are simple hollow sacs with glandular walls, and the organs are not bent on themselves as in Anodon, nor are there two cavities which differ in position and structure. The external openings (fig. 1, *Ro.*, *rp.*) are the renal reproductive apertures by which the excrete matters from the pericardial gland and the coelomoducts, together with the ova and spermatozoa, pass to the exterior. They are prominent vertically-placed slits, the long axis of the opening lying almost in the same direction as that of the organ itself and situated very near the distal end, rather on the free surface of the gland. The slit has prominent lips, which are often white in fresh or spirit specimens, and thus contrast with the brown colour of the organ itself.

The reno-pericardial opening is very difficult to find, and can only be made out with certainty by serial sections. The pericardium cannot be injected from the renal organs, so that the passage of fluids from the coelomoducts to the pericardium is prevented. It has been pointed out that the pericardium is prolonged at each side of the digestive gland, and between it and the adductor, so as to form two somewhat deep pouches, in which lie the distal portions of the two auricles communicating with the efferent branchial vessels. In the pallial cavity, very close to the digestive gland, there is a nook formed by the mantle, visceral mass and digestive gland. Just at this point the efferent branchial vessel and the upper end of the renal organ lie alongside each other, and the former passes into the pericardium; the latter a little distance below its upper extremity gives off a tube which is lined by columnar ciliated cells, differing much in appearance from the glandular cells of the rest of the renal organ. This reno-pericardial canal passes to the dorsal side of the efferent branchial vessel, and opens into the pericardium above it and rather to the outer side. Both renal organs communicate at their upper ends by a transverse branch running under the visceral mass above the adductor muscle. The cells lining this channel have the same appearance as those lining the rest of the cavity, but the walls are not folded and the space between them is but small.

The structure of the renal gland is as follows (figs. 42 and 43): Lying underneath the outer epithelium (fig. 43, *Ren. ep.*) there is a connective tissue layer which forms a definite sheath and supports the internal glandular layer. Longitudinal and circular muscle fibres occur in this connective tissue sheath. The inner surface of the gland, bounding the cavity, is complicated in its folding. This can be seen by slitting up the side of the renal organ, but better still by cutting transverse sections. The whole cavity is much reduced and divided up by these folds, longitudinal folds predominating (fig. 6), but they are not regular and appear to bifurcate and anastomose. The folds that are seen with the naked eye are really themselves made up of numerous folds, as shown by the sections (fig. 43); and so in this way the glandular area is increased very much, and the cavity broken up and reduced in size. Two layers are concerned in the formation of these folds, the connective tissue (fig. 42, *R. con.*) and the glandular layer (*Ren. c.*). From the prominent connective tissue sheath which surrounds the organ, folds are given off which support the epithelium. Thus, both layers are seen together forming the folds.

There are two series of spaces seen in sections through the gland—the lumen or gland cavity lined by epithelium with all its diverticula, and the blood spaces bounded by the connective tissue in which they lie (figs. 42 and 43, *Ren. r.*) and containing scattered corpuscles, so that the blood is only separated from the glandular epithelium by a thin layer of connective tissue.

The glandular epithelium is composed of cells which are about three times as tall as their width. The cells do not contain much stainable protoplasmic contents, and high magnification shows that they are much vacuolated with the protoplasm situated near to the cell bases, towards which end the nucleus is also to be found. The large vacuole occupying most of the cells is filled by a refractive colourless or slightly brown crystalline body, which is a concretion of excrete matter. The free surfaces of the cells facing the lumen of the gland bear delicate processes almost exactly like cilia, so that in some places it is very difficult to detect any difference. They are irregular in distribution, sometimes quite abundant, and have also a beaded appearance which makes them a little unlike cilia—which, moreover, have not been found on the cells of the renal organ of Lamellibranchs It is unusual for excretory cells (loaded with excrete matter in many cases) to have cilia, and I am inclined to think, therefore, that this very cilia-like appearance is due to an excretion which takes place in a fibrous manner. There are generally present in the lumen of the organ masses which look as if they contained these cilia-like processes. In the figure (fig. 52) these are too much like cilia, and are rather too regularly disposed. In addition to these processes there are always to be found cells in the act of extrusion, so that by actual dehiscence of the cells the excretion is thrown into the cavity of the duct. The opening to the exterior is lined for a short distance with non-glandular, more compact, normal ciliated epithelium, the lips being formed by a slight development of cushions of connective tissue.

In addition to the organ of Bojanus, excretion is carried on by the pericardial glands. These are confined to the auricles, to which they give a very distinct brown tint. The auricle has the wall thrown into numerous pockets, which increase its surface. It is formed of a single layer of epithelial cells (fig. 49, *Aur.*), somewhat flattened, and with prominent nuclei. Internal to this, there is a considerable amount of loose connective tissue with scattered muscle fibres, and amidst these lie the cells (*Aur. ex.*) which by reason of their contents give the brown colour to the surface. They are large, and very similar in form to those described in the connective tissue sheath of the alimentary canal, except that more protoplasm appears to be present; oval in shape, with the nucleus near one end, and the rest of the cell almost filled by a mass of some refractive structureless substance surrounded by a thin cortex of protoplasm. Usually, the large mass of cell contents shows a granular central portion of an olive green tint, and surrounding this a part which stains, like connective tissue and chitin, a light blue with Methyl-blue-eosin.

The two forms of excretory organs already described seem to perform different work. If indigo carmine solution is injected into the animal, it will be eliminated by the cells of the organs of Bojanus; whilst if ammonium carminate is injected, it is taken up by the pericardial excretory cells.

The latter cells, which have been described as placed chiefly on the auricles, occur also in the mantle, the visceral mass and around the intestine.

The first kind of cells, those lining the coelomoducts, have been found in Lamellibranchs to contain Urea or Uric Acid, whilst in *Pecten maximus* the excretory cells of the auricle have been found to contain Hippuric Acid (**18**). In both cases the contents are extruded, in the former into the cavity of the coelomoduct and in the latter into the pericardium (at least by the cells of the auricles), from whence they pass by the renal-pericardial openings into the coelomoducts, and so outwards.

Finally, there are granular eosinophilous cells, which are found in numbers along the mantle edge. In places they can be seen extruding their contents, and they probably also perform some excretory function, though since none are found in the connective tissue it is not easy to determine their origin.

REPRODUCTIVE ORGANS.

The genus Pecten is interesting because both unisexual and hermaphrodite species exist. *P. tenuicostatus* (Mighels), the giant scallop of America, is unisexual. *P. opercularis* and *P. maximus* are both hermaphrodite. In the two latter species the reproductive organs are posterior and ventral to the rudimentary foot, forming a tongue-like mass attached to and depending from the adductor muscle (fig. 1, *Go. o.* and *Go. s.*). They do not extend into the mantle or encroach upon other organs, even when expanded to their greatest extent in the spawning season.

When the sexual products are nearly ripe the organ is at its largest, and is firm in consistency as if the contents were pressing against their walls. At this time the male portion of the gland (fig. 1, *Go. s.*), which is situated most dorsally and anteriorly, extends to a point about midway between the mouth and the foot and abuts on the liver lobules at this point. It is rather flattened here, but from a point immediately below the foot it contracts considerably from side to side and becomes deeper. The deepest part is where the male abuts against the ovigerous portion, and the organ gradually tapers to a rounded point. Midway between this free end and the parieto-splanchnic ganglion it is attached to the adductor by the connective tissue that covers the under surface of the muscle and the adjacent organs of Bojanus. The whole of this mass is not gonad, for, as described above, part of the alimentary canal courses through it (fig. 1, *Al. c. 3*, *Al. c. 4*), and is thus surrounded by the sexual organs; but the intestine does not penetrate to the ovigerous part in *P. opercularis*, whereas in *P. maximus* it runs almost to the end of the mass.

The ovigerous part occupies the hinder end, and can be easily distinguished from the male part when the products are ripe, for it has a beautiful vermilion-pink colour, becoming deeper as the eggs approach maturity. During the ripening of the products, the male part becomes cream coloured, and the junction of the cream and red is quite sharp though irregular in outline, and there may be islands of ovigerous tissue surrounded completely by the male organ, or the female part may extend a considerable way forwards into the centre of the seminal portion which then lies on the exterior. After discharge of the contents, or when collected before the products have developed, the organ has a shrunken and flabby appearance, and is of a yellowish-brown colour, and the intestine may be seen through it.

The male and female products of the one individual do not appear to be ripe at quite the same time, though there cannot be much difference in this respect. Fullarton found that when the ova were quite ripe the spermatozoa had either been shed or were not quite ripe, some being found with ripe ova and sperms not ripe and others just the converse. The same applies to *P. maximus*, and the difference in the time of maturity of ova and sperms cannot be more than a few days.

Specimens of *P. opercularis* with ripe gonads have been obtained at all times of the year on the scallop beds in the Firth of Forth, the maximum of reproductive activity being, however, in July and August. *Pecten maximus* has been dredged off Port Erin with ripe gonads in December, April, May and throughout the summer, and in the same condition off Belfast Lough in February and March, so that the reproductive activity extends at least over the greater part of the year.

The gonads have one opening on each side into the renal organ, situated near the pericardial end, at the level of the prominence on each side of the visceral mass near the attachment of the lower ends of the inner labial palps. The ducts can be traced in serial sections, and although the opening cannot be made out in dissections, it is possible, by pressing the ripe gonad, to force the products out into the renal organ, though care must be taken not to force them through one of the veins leading from the visceral mass, which may be easily mistaken for the oviducts. The products of the gonads must be poured directly into the sea through the renal organ, and thus fertilisation takes place externally.

The gonad consists of many branched tubuli (fig. 53, *Go. d.*), bearing numerous almost spherical sacs, the alveoli (fig. 53, *Go. al. s.* and *Go. al. o.*). The sexual products, spermatozoa or ova according to the position, arise by the proliferation of the cells forming the germinal epithelium on the walls of the alveoli. As the gonads ripen the alveoli become filled with the products, and thus there is a general expansion of the reproductive mass, and the alveoli near the surface appear to the naked eye as rounded elevations or as small eggs.

In teased preparations of the ripe ovary the alveoli are so numerous that it is difficult to see the connecting tubules, but in sections they are easily traced by their ciliated lining, and may be seen gradually joining up to form the reproductive ducts. These ducts can only be definitely traced by serial sections, but in some specimens of *P. maximus* the duct on the right side, which is by far the largest, can be seen with the naked eye as a thick white thread running parallel with, and very close to, the junction of visceral mass and renal organ until it opens into the latter. If the point of an injecting syringe is inserted near the opening, this duct may sometimes be injected, but unless it is visible through being near the surface, care must be taken not to mistake an injected arterial vessel for it. The duct on the left side is much smaller and only extends a little way, acting as conduit for the male portion on the left side in the neighbourhood of its opening. The rest of the gonad is supplied by branches of the large duct which opens on the right. The main ducts are lined by an epithelial layer of columnar ciliated cells (fig. 54, *Go. d.*), the height of which is about twice the diameter, while the cilia are about as long as the cells. This epithelial layer is supported by somewhat delicate connective tissue which is continuous with the scattered strands that cross in all directions and pass round the alveoli and the ducts, forming a framework for the reproductive organs.

This columnar ciliated epithelium passes into the flattened germinal epithelium (fig. 53, *Ge. ep.*) lining the alveoli, and in the ovarian region ova in various stages of development (fig. 53, *O'.*) can be seen attached to the wall, but gradually projecting more and more as they increase in size until they are set free in the cavity (fig. 53, *O.*).

The ova are large cells about 0·05 mm. in size, and when lying in the alveoli are polyhedral in shape. The nucleus is very large, spherical or oval in shape, and about two-thirds the diameter of the cell. A delicate network is present, extending over the nucleus, and in addition, they are small granules staining with eosin, and a conspicuous nucleolus. This is situated close to the periphery at one side of the nucleus. In some cells more than one nucleolus is present, there being often a large and two smaller ones at its sides.

The cytoplasm is granular and dense, and around the ovum is a prominent vitelline membrane which leaves an opening—the micropyle, at the point where the egg remained last attached to the epithelium of the alveolus.

The spermatozoa (fig. 53, *S.*) are rather small and of the typical shape; in fixed preparations the head is oval in shape and stains very intensely. From the middle of the broad end a long flagellum arises. In the alveolus the tails of the spermatozoa are generally all directed in the same way towards a point in the centre or nearer one end where the duct opens, whilst the heads are directed towards the wall of the alveolus. Both spermatozoa and ova travel along the same gonoducts to the exterior.

EMBRYOLOGY.

I have been unable to obtain enough specimens of *P. maximus* sufficiently ripe at the same time to artificially fertilise the eggs, but hope to continue this work at some future date. It has been already pointed out that the generative organs are not ripe simultaneously, but that a very short interval of time separates them.

The development of *P. opercularis* has been worked out by Fullarton (**40**). He fertilised the eggs by mincing the ovarian and seminal parts into two glass vessels of sea water, which, after straining through muslin, were mixed.

The polyhedral egg cells soon assume a spherical shape, the time varying according to the state of maturity, from a few minutes to half an hour. A vitelline membrane is clearly visible, and a delicate hyaline investment can be sometimes observed outside the bounding wall of the ovum. A considerable quantity of granular deutoplasm is also present, which partially obscures the nucleus. The size of the ovum is 0·068 mm. After fertilisation a polar globule is extruded, which in many cases remains in contact with the oosphere for a considerable time. The next visible change that takes place is that the contents become much clearer at the animal pole. This end is prolonged, so that the oosphere becomes pear shaped, and eventually a constriction appears and the embryo divides into a macromere and a micromere, the latter occupying the animal pole. A second and a third micromere are then budded off from the macromere, and so the four-celled stage is reached. The micromeres now become active, and each sub-divides into two, and they gradually spread over the surface of the macromere until it is almost covered by them. The macromere now begins to segment, two equal cells resulting from the first division, which are the first two cells of the endoderm. These continue to divide, and are completely enclosed by the micromeres, which form the ectoderm and become ciliated; the continuity is broken at one point, however—the blastopore. The next occurrence is the development of a furrow proceeding from a small depression on the surface of the embryo, which is the early shell gland.

A velum is developed as a circular ridge covered with long cilia, and encircling the embryo between the blastopore and the shell gland. The stages following have not been observed in *P. opercularis*, but probably there are one or two long apical cilia developed in the centre of the velum, and the embryo elongates in the direction of the axis of these cilia, though in the stages which Fullarton observed with the shell valves developed, there were neither apical cilia nor flagellum present. A trochospere larva is thus formed, with a velum but no shell. Later the mantle folds are developed and two shell valves, and the veliger stage is entered upon, locomotion still being carried on by the velum, which is extended beyond the margins of the valves and is retracted by two velar muscles. A single adductor, the anterior, is developed, and the alimentary canal formed; the mouth-opening being just posterior to the velum, and the anus close to the mouth.

ECONOMIC IMPORTANCE.

Pecten opercularis occurs in large beds which are found in many localities round the British Isles. In most of these places little use seems to be made of the scallops, though they might be of considerable value both as food and bait. The species occurs in such abundance in the Firth of Forth that an important industry has arisen, which once employed a considerable number of hands, though in recent years the number has diminished. In Scotland, *P. opercularis* is known as the "clam," though it must be remembered that this name has been applied also to other genera of marine Lamellibranchs, both round our own coasts and in America.

The condition most favourable for the formation of a Pecten bed is a shelly bottom, with a little mud. Too much fine mud is detrimental. The most favourable depths are from five to twenty fathoms, though the species occurs sporadically in much deeper water, but not in communities. The animal seems to be readily injured by a low temperature, and in the year 1895 large numbers were killed in the Firth of Forth by the long continued cold weather.

Scallop dredging extends almost throughout the year in the Firth of Forth, but very little goes on during the time of the herring fishing in summer, and this is the time when the shellfish are least valuable, for owing to their gaping shells and their habit of clapping the valves the sea water cannot be enclosed, as in the mussel or oyster, and the animal, consequently, soon dies when removed from the water.

The dredge used for the purpose of clam fishing is an oyster dredge of five to six feet in breadth of mouth. The net attached to the frame is made up, on the lower side, of a series of iron rings laced together with short pieces of wire, so that repairs can be very easily made with additional rings and wire. The upper side of the net is composed of ordinary twine. The clams are mostly used for the baiting of long lines, five hundred clams being required for a line of one thousand hooks.

With regard to the value of clam as bait, experiments have been carried out by the Scottish Fishery Board, from whose reports the figures given have been taken. The lugworm (*Arenicola*) seems to have given the best results, though the mussel (*Mytilus*) and clam (*Pecten*) come close after, and the three are probably about equally successful. The clams are preferred most in winter and least in summer, when they soon die. Since the shell valves do not fit closely, as already pointed out, Pecten cannot stand as much exposure to the air as most of our edible molluscs, and this will always be a difficulty in transporting to the markets.

Pecten have been put to a most interesting use at the large trout hatchery of Howietown, near Stirling. The breeding trout in their fifth year are fed with more mussels and less horse flesh, and in the sixth year clams (Pecten) are substituted for mussels. It is found that the ova from trout of six to eight years of age have a pink colour when the fish are fed on clams. Trout thus fed on clams yield the smallest number, proportionately, of eggs, but these are of the largest size and darkest colour, and these have been found to be the most valuable ova for rearing purposes.

There seems to be no reason why the scallop should not become much more important as a source of food, and it is eaten both raw and cooked by those on the fishing grounds and a few others who are aware of the delicacy of its flavour. It has a peculiarly sweet taste, which is preferred by some to that of the oyster. At Billingsgate, *Pecten maximus* (known in the trade as "Escallops") are not marketed in summer. The season begins in November and continues until March, and generally the demand appears to exceed the supply. During the winter season of 1907-08 the supplies were the lightest for years, with prices, perhaps, the highest ever reached. Wholesale prices averaged from 25s. to 45s. per bag of twenty dozen. In the Liverpool Fish Market, the season is practically the same as at Billingsgate, viz., from November to May, and December is the heaviest month. The average number of scallops is about five hundred each week, and the price 1s. 3d. per dozen. They are caught by sailing trawlers in the Irish Sea, the greatest quantities being found between Fleetwood and Douglas (Isle of Man). In the Isle of Man, *Pecten maximus* is known locally as "tanrogan," and *P. opercularis* as "queens." When trawled they are occasionally used as food, and a few connoisseurs cure and pot them.

Little or no use seems to be made of the large bed off Port Erin, which might supply the fishermen of that place and Peel with bait for the long lines.

The following are the quantities and values of the "clams" (*P. opercularis*) landed from the Firth of Forth beds for the last twenty years, from 1888:—

1888, 20,674 cwt.	£2,918	1898, 14,013 cwt.	£1,595
1889, 23,811 cwt.	2,563	1899, 12,125 cwt.	1,485
1890, 25,706 cwt.	3,297	1900, 6,372 cwt.	861
1891, 28,512 cwt.	3,347	1901, 6,587 cwt.	802
1892, 20,769 cwt.	2,736	1902, 4,320 cwt.	586
1893, 17,684 cwt.	2,388	1903, 4,606 cwt.	637
1894, 25,583 cwt.	3,317	1904, 6,993 cwt.	944
1895, 19,535 cwt.	2,645	1905, 7,848 cwt.	1,129
1896, 22,353 cwt.	2,915	1906, 7,391 cwt.	1,083
1897, 19,258 cwt.	2,408	1907, 7,197 cwt.	953

It will be seen from the above that a great falling off in the clam industry is recorded, especially beginning with the year 1900. This, together with the slight increase from the years 1904 onwards is to be put down to the decline in line fishing and the slight revival in the last few years recorded, and not to any decrease in the actual number of the Pecten on the beds.

No figures are given in the English Fishery Reports of the value or quantity of scallops landed, but they are recorded as being fished from several places - Scarborough, Brightlingsea, Dover, Newhaven, Weymouth, Portsmouth, &c.—in almost every case the scallop fishing being carried on during the winter months.

Probably unrecorded or occasional scallop fishing is carried on at many other places, not as an independent industry, but to obtain bait for the lines of a few local fishermen. It is certain, moreover, that much could be done to locate, improve and exploit beds of this useful shellfish if a greater demand for it arose in the future, either as human food or as bait for the fishing lines.

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DESCRIPTION OF PLATES.

REFERENCE LETTERS.

a. = Hepatic artery.
A. add. = Adductor artery.
A. c. = Circumpallial artery.
A. l. = Labial arteries.
A. p. = Pedal artery.
A. p. a. = Ant. pallial artery.
A. p.p. = Post. pallial artery.
A. r. = Rectal artery.
A. s. = Striped part of adductor.
A. u. = Unstriped ditto.
A. v. = Visceral arteries.
Al, Al′. Al″. = Alveolus digest. gland.
Al. c 1. = Oesophagus.
Al. c. 2. = Stomach.
A. l c. 2′ = Ant. left lat. depression, ditto.
Al. c. 2″ = Post. ditto.
Al. c. 3. = Descend. loop of intestine.
Al. c. 4. = Ascend. loop of intestine.
Al. c. 5. = Rectum.
An. = Anus.
Ao. a. = Anterior aorta.
Ao. p. = Posterior aorta.
Arg. = Argentea.
Aur. = Auricle.
Aur′. = Wall ditto.
Aur. C. = Transv. connect. ditto.
Aur. ex. = Excret. cells ditto.
Aur. m. = Muscles ditto.
Ax. f. = Axial fibril of Rods.
Bl. c. = Blood corpuscles.
B. g. = Byssal Gland.
B. g. c. = Byssus cells.
Br. = Branchia.
Br. a. = Ascending lamella of Branch.
Br. a′. = Termination ditto.
Br. aff. = Affer. branchial vein.
Br. aff′. = Entrance to ditto.
Br. ax. = Ctenidial axis.
Br. d. = Descending lamella.
Br. eff. = Effer. branchial vein.
Br. j. l. = Interlamellar septum.
Br. m. = Long. mus. ctenidium.
Br. r. = Respir. expans'n prin. filam't.
Br. v. = Blood vessel of ditto.
C. fr. = Frontal cilia.
C. l. = Lateral cilia.
Ch. D. = Dark staining chitin.
Ch. L. = Light staining chitin.
Com. = Cerebro-pleural comm.
Con. cp. = Cerebro-pedal conn.
Con. cv. = Cerebro-visceral conn.
Cor. = Cornea.
Cor. ps. = Pseudo cornea.
Cris. = Crystall. style, cav. of intest.
D. c. = Cell of Distal cell layer.
D. c. l. = Distal cell layer.
D. g. = Digest. gland duct.
Dg. = Digestive gland.
E. = Eye.
E. Mn. = Epith. of Mantle.
E. st. = Eye stalk.
Eos. = Eosinophil. cells.
Ex. = Wandering excret. cell.
F. = Foot.
F. s. = Foot sucker.
Fil. n. = Nerve of gill filament.
Fil. o. = Ordinary gill fil.
Fil. p. = Prin. gill fil.
Fil. sep. = Intra-fil. septum.
G. ant. = Ant. lobes of visc. ganglion.
G. cb. = Cerebro-pleural gang.
G. c. l. = Post. centr. lobes, visc. gang.
G. lat. = Lat. lobes, visc. gang.
G. Osp. = Osphradial ganglion.
G. p. = Pedal ganglion.
G. sp. = Visceral gangl.
Ge. ep. = Germinal epith.
Go. al. o. = Ovigerous alveolus.
Go. al. s. = Seminal alveolus.
Go. d. = Gonoduct.
Go. o. = Ovigerous part of gonad.
Go. s. = Seminal part of gonad.
Gr. = Granular cells, digest. gland.
I. = Iris.
In. c. o. = Outer interstit. cell.
In. c. i. = Inner interstit. cell.
L. = Lens.
L. cl. = Leucocytic clumps
L. p. e. = R. ext. labial palp.
L. p. i. = R. int. ditto.
Lc. = Leucocytes.
Lg. p. = Ligament pit.
Lp. = Lips.
Lp. l. = Lower lip.
Lp. u. = Upper lip.
M. = Mouth.
Mn. = Mantle lobe.
Mu. g. = Mucous glands, foot.
Mu. g. c. = Compound ditto.
N. br. = Ctenidial nerve.
N. c. = Circumpallial nerve.
N. l. = Nerves, labial palps.

N. ot. = Otocyst nerve.
N. p. = Pedal nerves.
N. pa. = Ant. pallial nerve.
N. pall. = Visceral pallial nerve.
N. pp. = Post. pallial nerve.
O. = Ova.
O′ = Young ovum.
Op. F. = Ophthal. pallial fold.
Op. m. = Eye stalk muscles.
Op. n. = Optic nerve.
Op. n. i. = Inner branch ditto.
Op. n. o. = Outer branch ditto.
Ot. = Otocyst.
P. = Periostracum.
P. b. = Byssal groove.
P. gr. = Periostracal groove.
P. M. r. = Radial pall. muscles.
P. s. = Periostracal glands.
Per. = Pericardium.
Pig. = Pigment cells.
R. = Rods of retina.
R. C. = Rod-cells ditto.
R. C. n. = Nuclei, rod cells.
R. C. p. = Pseudo-rod cells.
Ro. = Renal organ.
Ro. c. = Gland. epith. ditto.
Ro. c′. = Ditto, with concretions.
Ro. con. = Connect. tissue, renal org.
Ro. ep. = Epithel., renal org.
Ro. m. = Intrinsic muscles, renal org.
Ro. rp. = Reno-reprod. apert.
Ro. v. = Renal veins.
S. = Spermatozoa.
S. D. = Dors. venous sinus.
S. m. i. = Basement membrane.
S. m. o. = Sieve membrane.
S. V. r. = R. vent. venous sinus.
Scl. = Sclerotica.
Sep. = Septum.
Sh. a. = Auricula of shell.
Sh. F. = Shell fold, mantle.
Sh. m. = Calcar. layer of add. impress.
Sh. p. = Artic. surf. of shell.
T. = Tapetum.
Tn. = Tentacle.
Tn. v. = Velar tentacle.
Tu. m. = Tunica muscularis.
Tu. p. = Tunica propria.
V. = Velum.
V. a. = Adductor veins.
V. h. = Hepatic vein.
V. M. = Radial velar muscles.
V. M. a. = Attach. of velar musc.
V. M. c. = Concent. velar musc.
V. p. = Pedal vein.
V. pall. = Pallial vein.
V. v. = Visceral veins.
Ven. = Ventricle.

PLATE I.

Fig. A. *P. opercularis*, right valve, showing byssal notch. Natural size.

Fig. B. *P. opercularis*, left valve. Natural size.

Fig. C. *P. maximus*, exterior R. valve (young). × $\frac{2}{3}$.

Fig. D. *P. maximus*, exterior L. valve (young). × $\frac{2}{3}$.

Fig. E. *P. maximus*, interior of R. valve, showing adductor impression and pallial line (slightly darkened), also ligament and ridges of hinge area. × $\frac{2}{3}$.

Fig. F. *P. maximus*, interior of L. valve; pigmented specimen showing muscular impressions. × $\frac{2}{3}$.

PLATE II.

Fig. 1. *P. maximus*, general anatomy, R. valve and mantle lobe and right ctenidium removed.

Fig. 2. Transverse section through rib of shell (*P. opercularis*). × 26.

Fig. 3. R. mantle lobe showing distribution of pallial nerves and muscles. Nat. size.

PLATE III.

Fig. 4. Transv. sect. of mantle edge and velum. × 20.

Fig. 5. Epithelium with eosinophilous cells, from the mantle. × 500.

Fig. 6. Transv. section of periostracal groove. × 350.

Fig. 7. Foot, showing pedal groove, &c.

Fig. 8. Transverse section through foot, along A. B., fig. 7. × 20.

Fig. 9. Section through byssal gland. × 130.

Fig. 10. Mucous glands from foot (*P. maximus*). × 480.

PLATE IV.

Fig. 11. *P. maximus*, blood vessels of R. mantle lobe injected with lard mixture.

Fig. 12. Renal organ, slit open, to show ridges and vessels on inner surface. Natural size.

Fig. 13. Heart, distended with air. × 2.

Fig. 14. Arterial system injected (*P. maximus*). Pallial arteries omitted.

Fig. 15. Leucocytes, and " clump " or pseudo-plasmodia. × 700.

PLATE V.

Fig. 16. Diagram of vessels of ctenidium.
Fig. 17. Arteries of lips and labial palps. Nat. size.
Fig. 18. Part of venous system of *P. maximus*, from injections.
Fig. 19. Ventricle and anterior aorta.
Fig. 20. Trans. section (diagram.) of ctenidium through prin. filaments, showing course of blood. × 4.
Fig. 21. Section of ctenidium, transverse to filaments, at level of top of ascending filaments. × 130.

PLATE VI.

Fig. 22. Section of ctenidium trans. to filaments, near free margin, showing both demibranchs with interlamellar junctions. × 110.
Fig. 23. Trans. section of principal and four ordinary filaments, near base, showing respiratory expansion. × 480.
Fig. 24. Section of respiratory expansion of prin. filament in same plane as ctenidium. × 10.
Fig. 25. Respir. expansion of a principal filament. × 20.
Fig. 26. General view of nervous system (*P. maximus*).
Fig. 27. Cerebro-pleural and pedal ganglia.
Fig. 28. Visceral ganglia (*P. maximus*), showing osphradial ganglia and chief nerve trunks.

PLATE VII.

Fig. 29. Longitudinal section of eye (*P. maximus*). × 150.
Fig. 30. Retinophorae, with rods and ganglionic cell layers (semi-diagram.).
Fig. 31. Cells of outer ganglionic layer. Zeiss apo. 1·5, with comp. oc. 4.

Fig. 32. Trans section of rods. Zeiss apo. 1·5.

Fig. 33. Trans. section of retinophorae. Zeiss. apo. 1·5.

Fig. 34. Argentea in surface view. Zeiss apo. 1·5.

Fig. 35. Epithelial cells of eye stalk. Trans. sect. Zeiss apo. 1·5.

Plate VIII.

Fig. 36. Alimentary canal of *P. maximus.* Nat. size.

Fig. 37. Trans. sect. through upper part of descending loop of intestine, showing division into two compartments. × 40.

Fig. 38. Left inside of stomach, showing cavities into which ducts open.

Fig. 39. Mouth, lips (separated) and labial palps.

Fig. 40. Section of internal labial palp, across ridges. × 66.

Fig. 41. Crystalline style of *P. maximus*, showing two conditions. Natural size.

Fig. 41*a*. Trans. section through crystalline style. × 7.

Fig. 42. Section of wall of intestine (same plane as fig. 37), showing cells of crystalline style cavity. × 244.

Fig. 43. Section of posterior part of ventricle and rectum. × 25.

Fig. 44. Wall of rectum, same section as fig. 43. × 300.

Fig. 44*a*. Wandering excretory cell (*Ex.*). × 300.

Fig. 45. Trans. section of ctenidial axis and bases of filaments, showing latter opening into afferent branchial vessel. × 16,

PLATE IX.

Fig. 46. Dorso-ventral section of small *P. opercularis*, through centre of adductor. × 5.

Fig. 47. Section of small *P. opercularis* (same plane as fig. 46), through digestive gland and anterior end of adductor. × 5.

Fig. 48. Section of small *P. opercularis* (same plane), anterior to adductor muscle through visceral mass. × 5.

Fig. 49. Section of wall of auricle, showing the excretory cells of pericardial gland. Zeiss apo. 1·5.

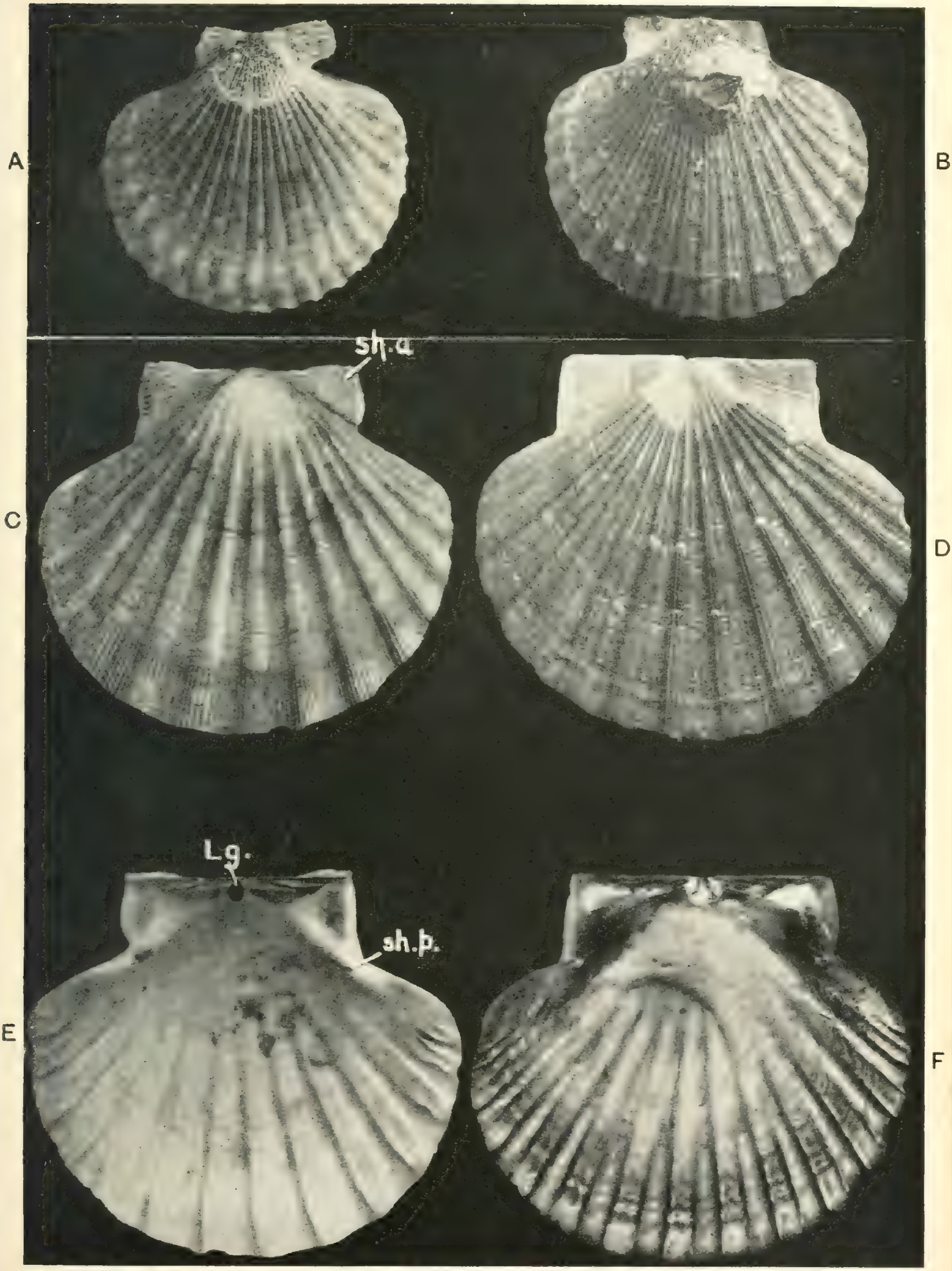
Fig. 50. Section of digestive gland, showing alveoli with pigment, and digestive ducts. × 170.

Fig. 51. Trans. section through renal organ. × 50.

Fig. 52. Part of previous section more highly magnified. × 400.

Fig. 53. Section through ovigerous and seminal alveoli of gonad (almost ripe). × 200.

Fig. 54. Striped muscle fibres from adductor, in surface (*b*) and edge view (*c*). Zeiss apo. 1·5 mm.



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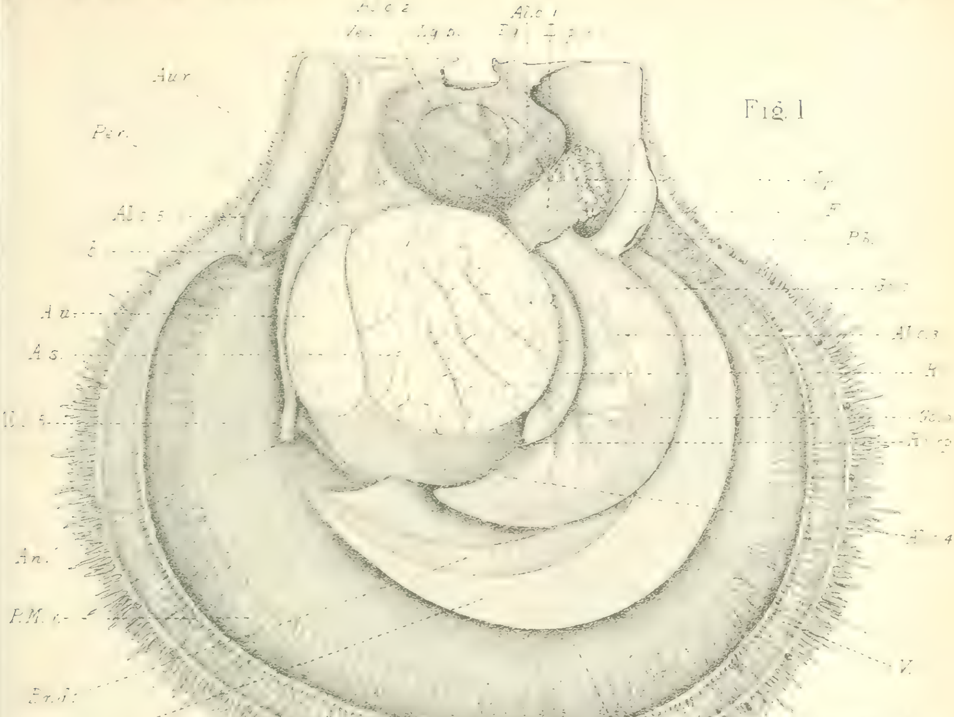

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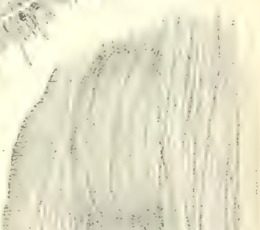

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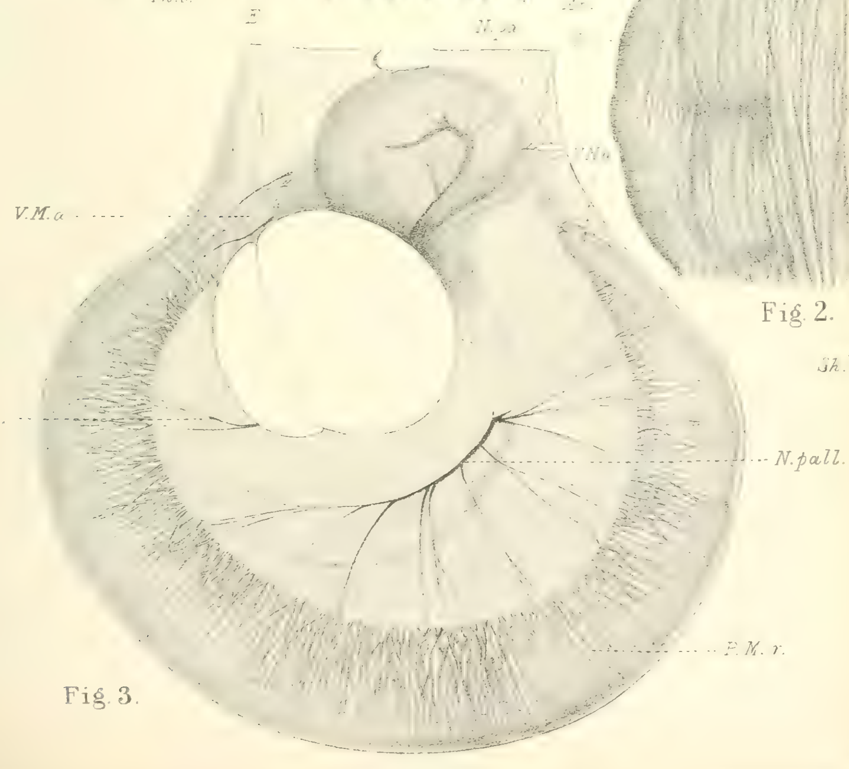

Fig. 3.

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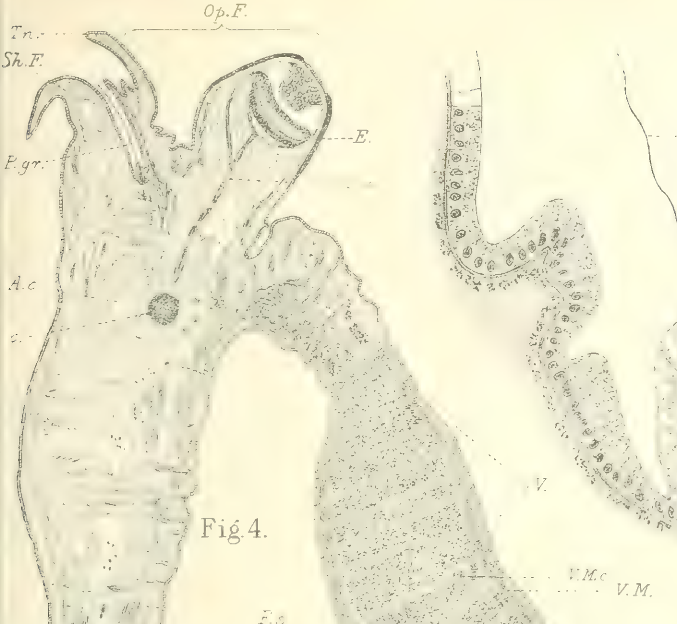

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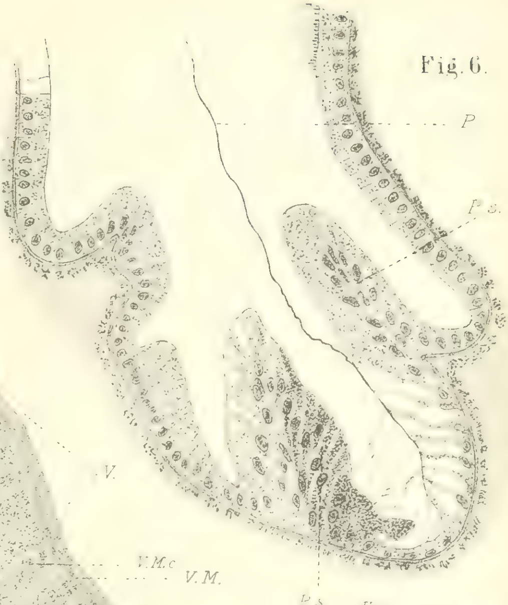

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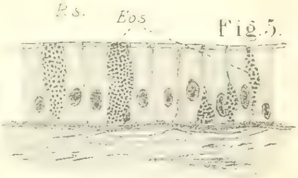

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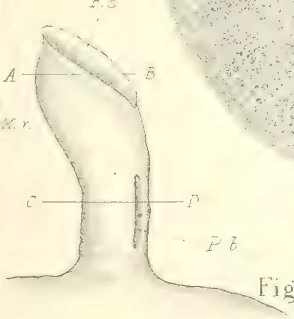

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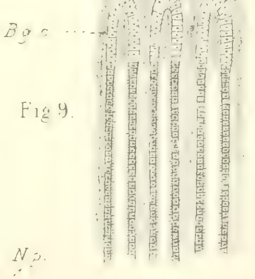

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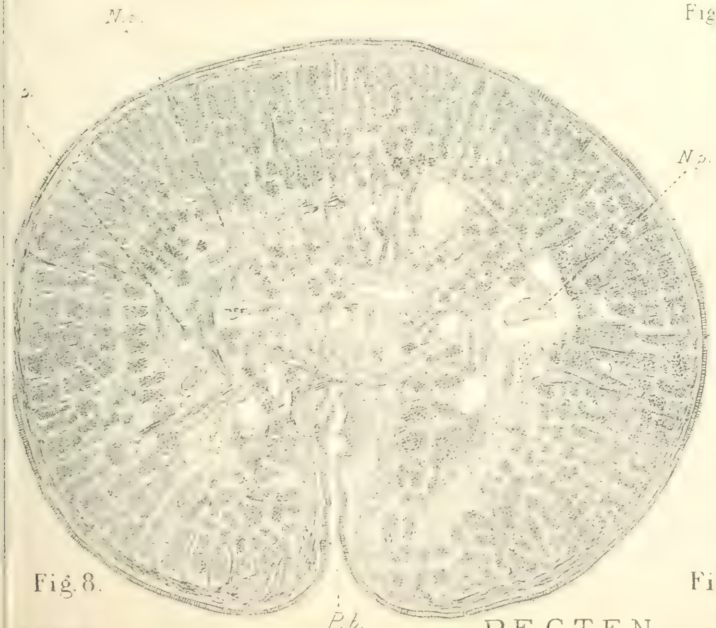

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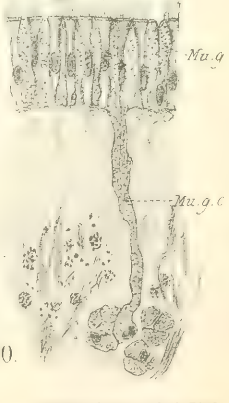

Fig. 10.

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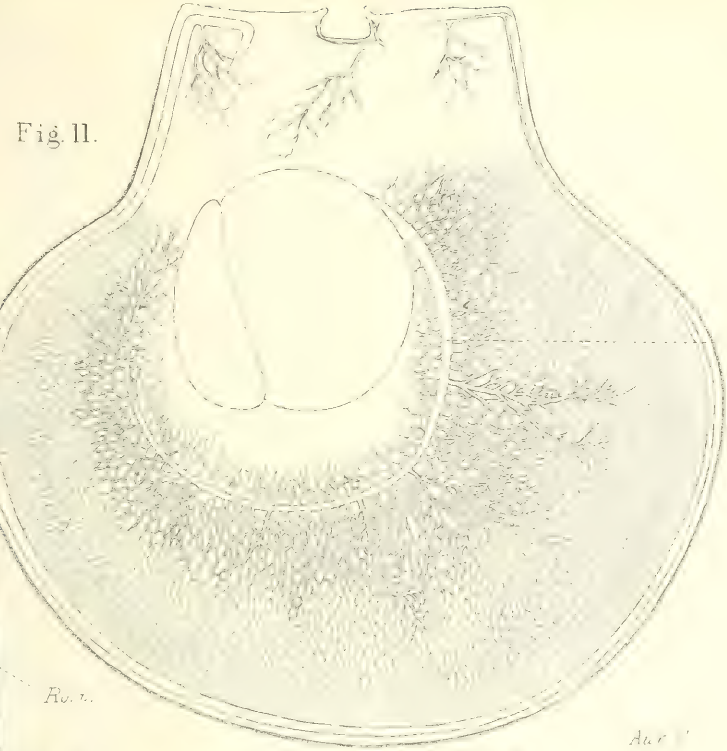

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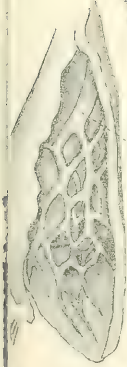

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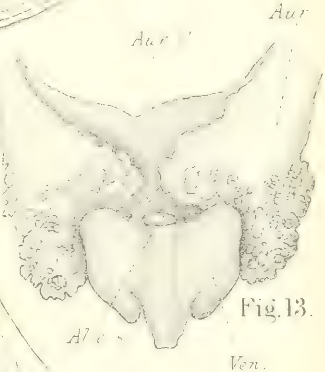

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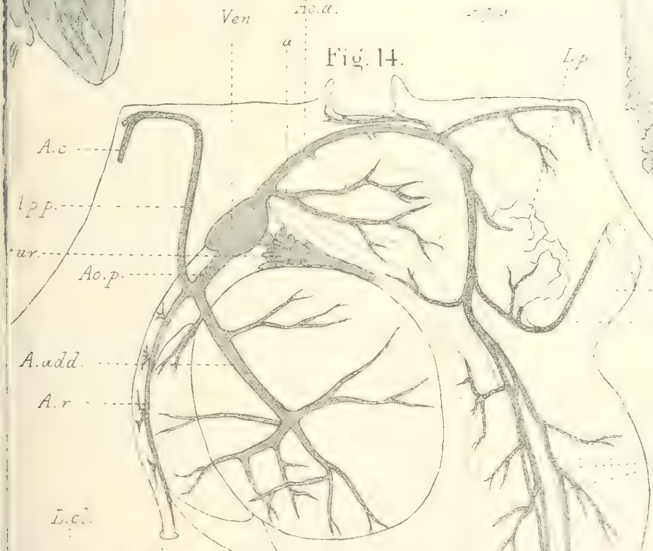

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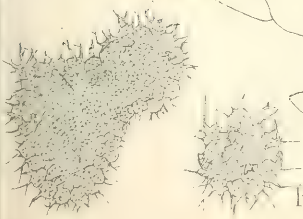

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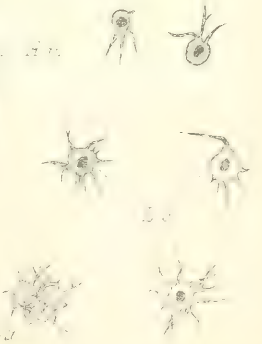

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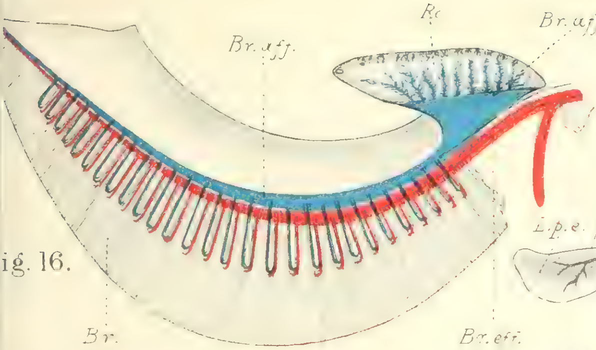

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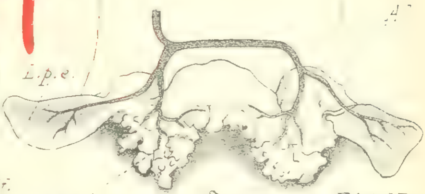

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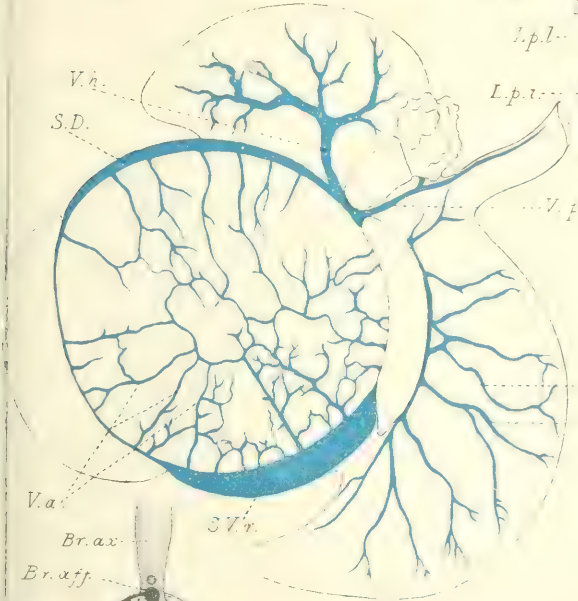

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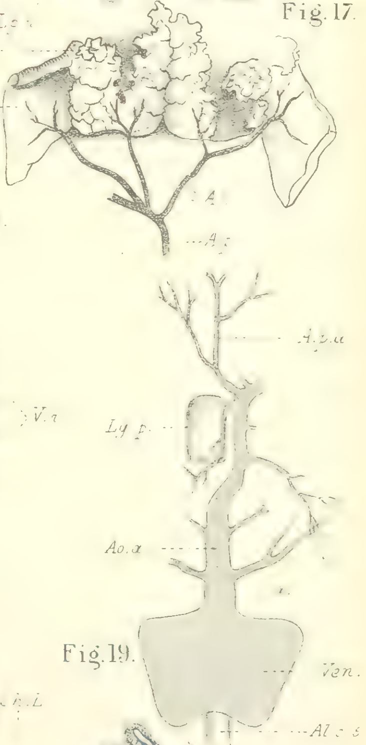

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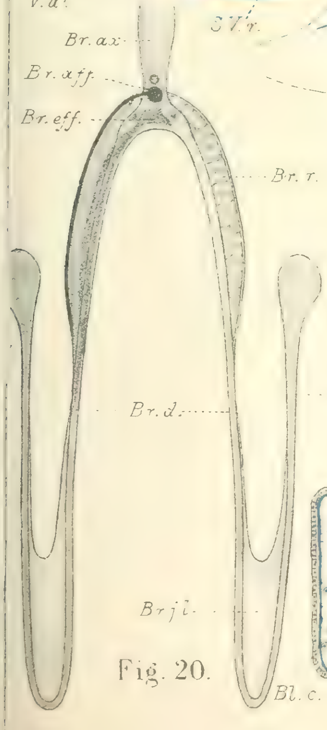

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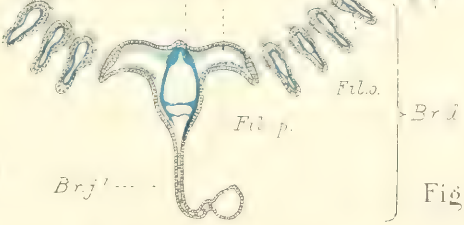

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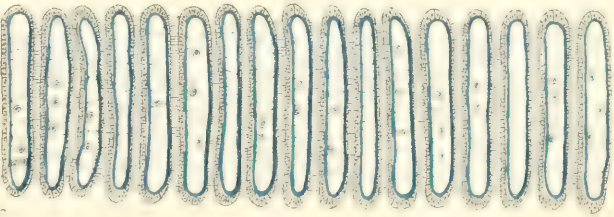

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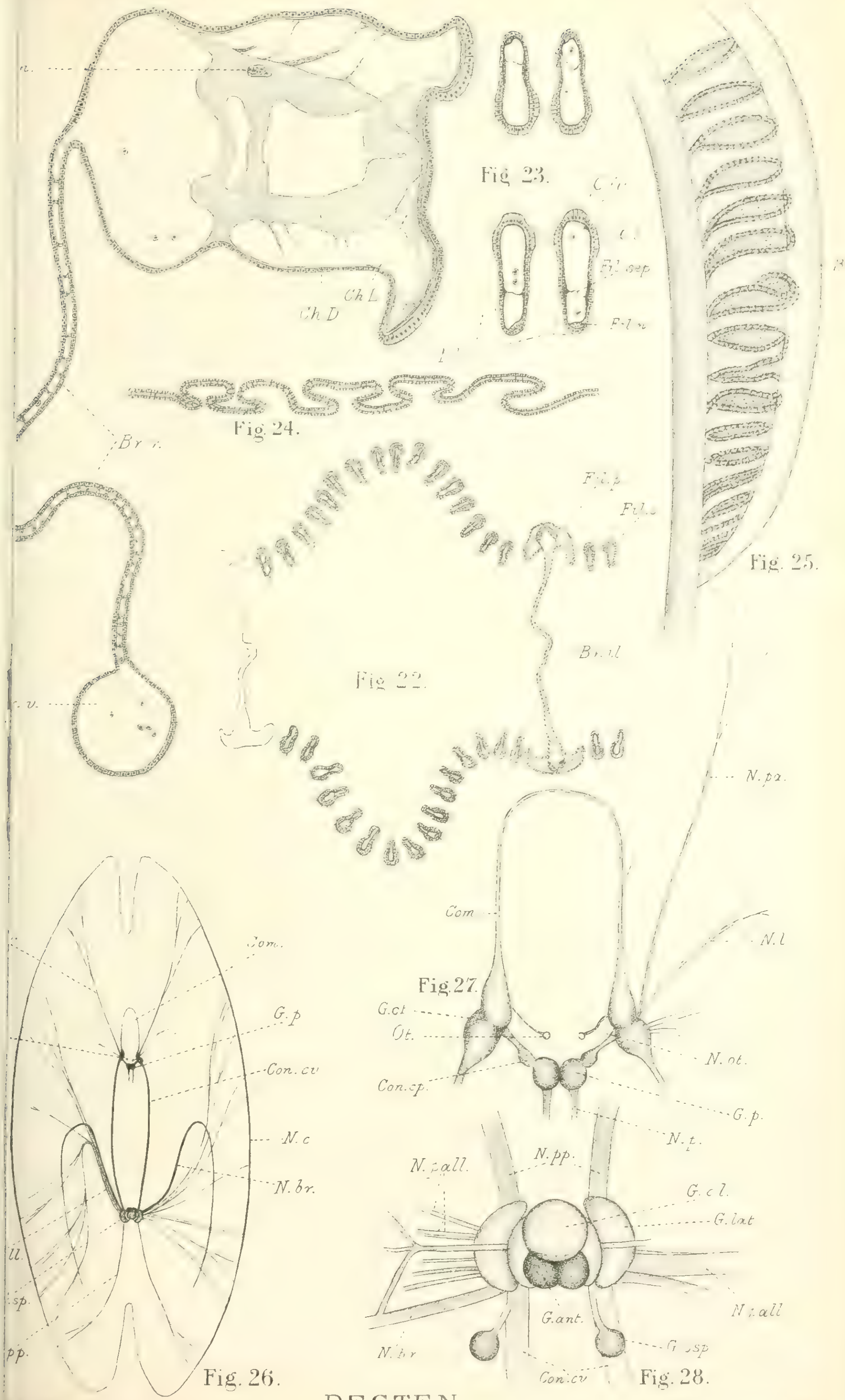

Fig. 22.

Fig. 23.

Fig. 24.

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Fig. 26.

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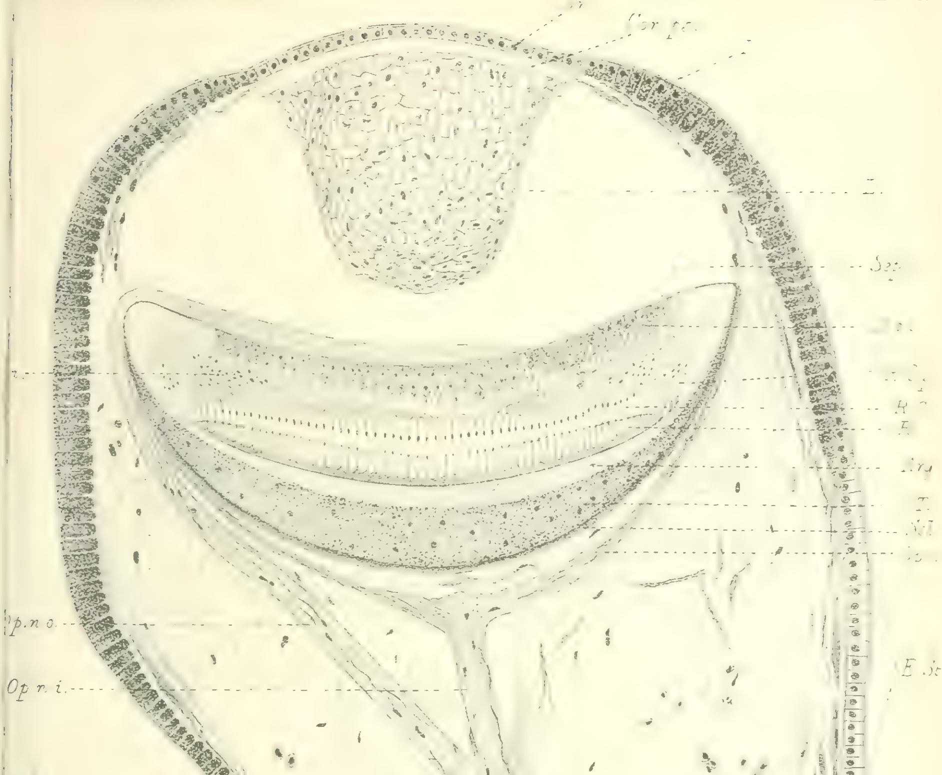

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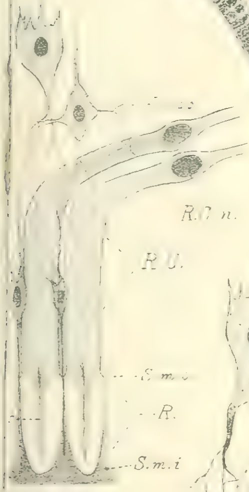

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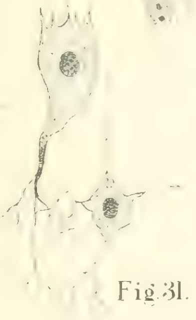

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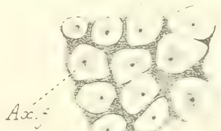

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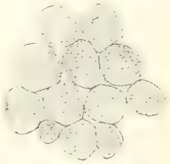

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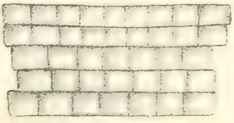

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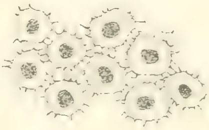

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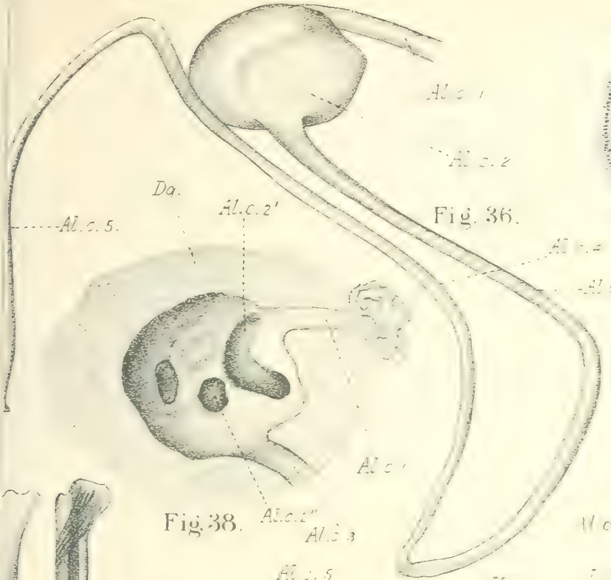

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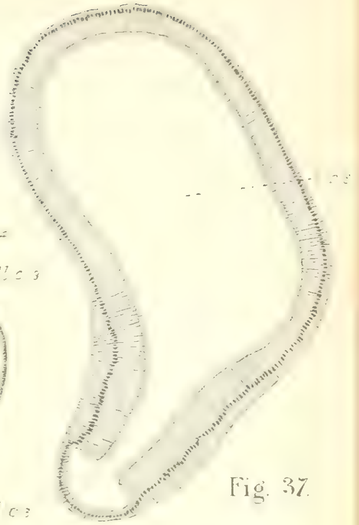

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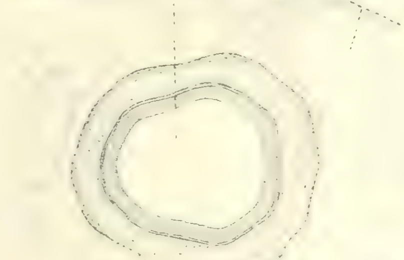

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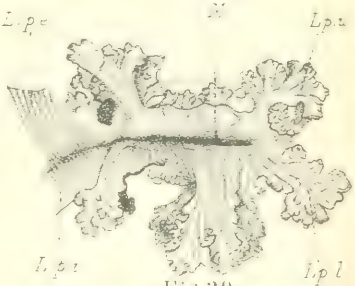

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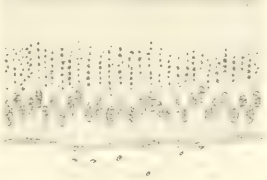

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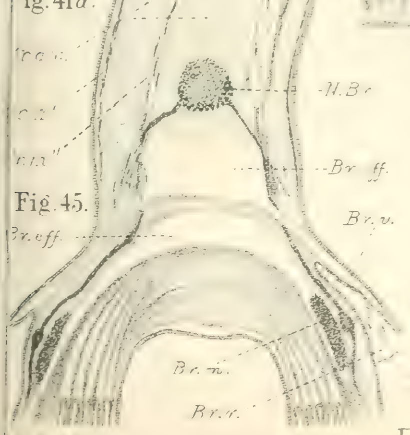

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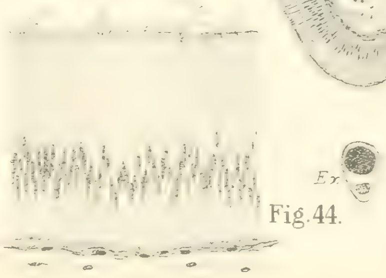

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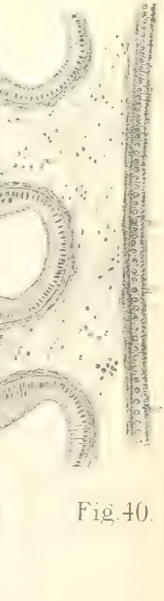

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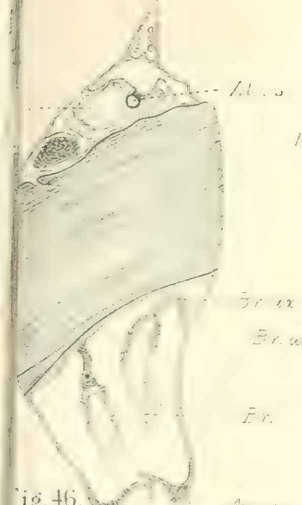

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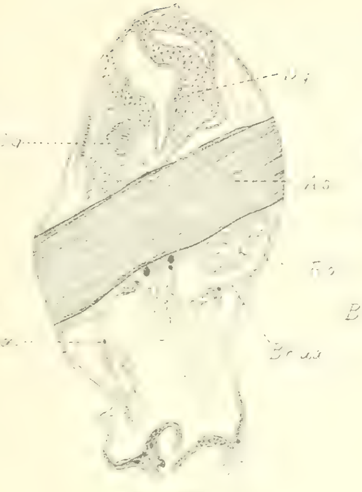

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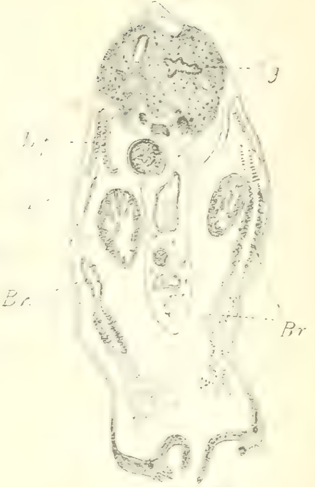

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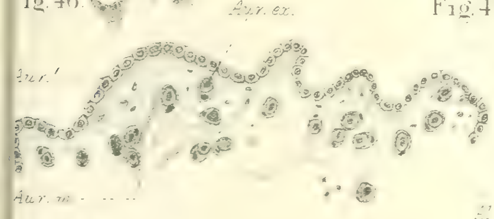

Fig. 49.

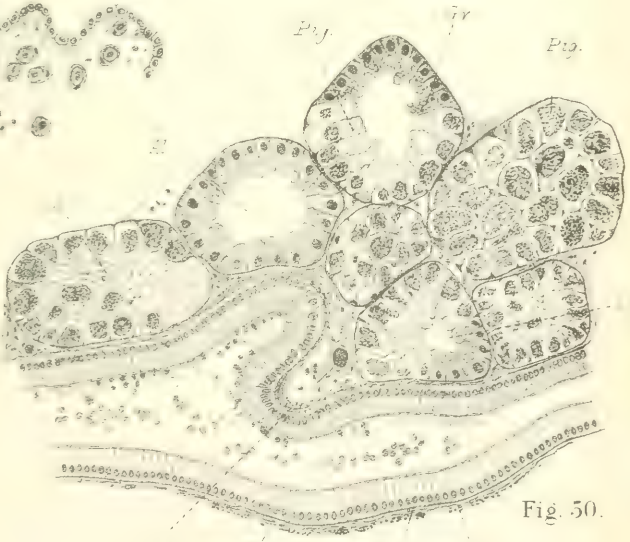

Fig. 50.

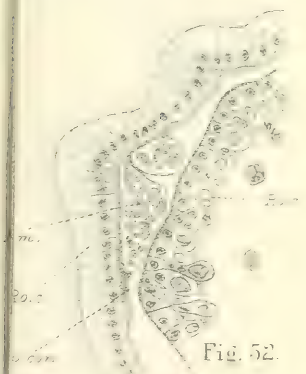

Fig. 52.

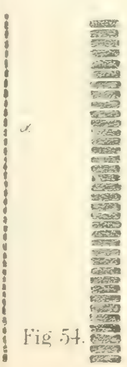

Fig. 54.

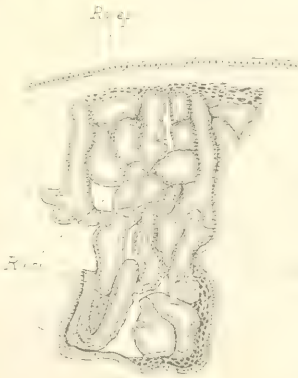

Fig. 51.

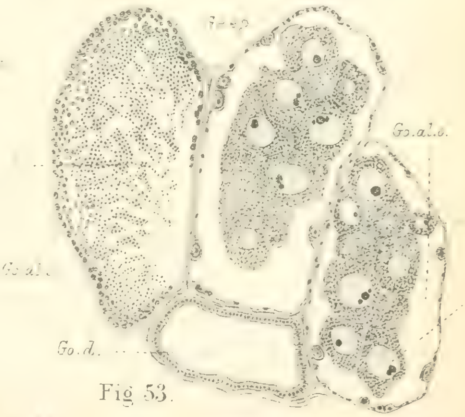

Fig. 53.

PECTEN

L.M.B.C. MEMOIRS.

No. XVIII. ELEDONE.

(The Octopod Cuttlefish.)

BY

ANNIE ISGROVE, M.Sc.

PREFACE.

The greater part of the work for this Memoir has been done in the Zoological Research Laboratory of the Manchester University. I take this opportunity of thanking Professor Hickson and Mr. Hewitt, of that University, for their helpful suggestions. Dr. Hoyle, of the Manchester Museum, also kindly lent me much of the literature of the subject, and assisted me in various ways. My thanks are due to the Council of the Marine Biological Association of Great Britain for the use of a table at the Plymouth Laboratory, during the Easter vacation, 1908, and also to Mr. Chadwick, of the Port Erin Biological Station, for several useful notes with which he supplied me as to the occurrence of *Eledone cirrosa* in that district, its habits, method of capture and other details.

INTRODUCTION.

Eledone cirrosa (Lamarck, 1798), or *Moschites cirrosa*, as it should be called according to the rules of the International Zoological Congress, belongs to one of the two genera of British Cephalopoda Octopoda. The following table, showing the classification adopted in Pelseneer's Text Book, illustrates the relation in which *Eledone* stands to other groups of Cephalopoda :—

Class CEPHALOPODA.

1. *Sub-class* Tetrabranchia, e.g. *Nautilus.*
2. *Sub-class* Dibranchia.
    - *Order* I. Decapoda, e.g. *Sepia.*
    - *Order* II. Octopoda.
        - *Family* Octopodidae—*Genus* ELEDONE.*

All Cephalopoda are aquatic marine animals. The genus *Eledone* occurs in the Mediterranean, round the Atlantic coasts of Europe, and elsewhere. *Eledone cirrosa* is the species confined to British waters, and is the only British representative of the genus. To the other British genus *Octopus*, belong *O. vulgaris* the common "Octopus," and *O. arcticus* a smaller deep-sea form.

Eledone cirrosa has been chosen for this Memoir because it is a convenient type for dissection, and may be fairly easily obtained at the Plymouth and Port Erin Biological Stations. It has also a certain economic importance, feeding on crabs and lobsters, and often extracting them from the crab and lobster pots put out by the fishermen. Popularly *E. cirrosa* is known as "the lesser Octopus," as it never attains the size of the common Octopus. It is also distinguishable by the single row of suckers on each arm.

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* As shown by Dr. Hoyle (Manchester Memoirs, Vol. XLV, No. 3, 1901, the correct generic names for "Octopus" and "Eledone" are *Polypus* and *Moschites* respectively. Hence the true title of *Eledone cirrosa* is *Moschites cirrosa*. Yet, as the names *Octopus* and *Eledone* have been in general use for 100 years or more, I think it on the whole better to continue to use them.

OCCURRENCE.

During the spring, Eledone is brought in from depths of 30 to 35 fathoms, at Plymouth and Port Erin, by trawlers and other fishermen. At this season, young specimens have also been taken occasionally in a few inches of water, at low water of spring tides, at Port Erin. The Eledones brought up in the trawl are probably caught while adhering to or creeping over stones and rocks, or while swimming near the sea bottom. They seem to occur in small groups of two to six in number. At Port Erin and Plymouth they are also taken in crab and lobster pots. These, at Port Erin, are put out at depths of from six fathoms inside the bay to twelve fathoms outside it. Although Eledone is always fed on Crustacea, when kept in captivity, and careful examination of about fifty specimens has shown no other than Crustacean food in the gut, yet occasionally at Port Erin, the fishermen have taken Eledone on hand lines baited with pieces of herring and mackerel. The mouths and oral surfaces of such specimens are lacerated by the hook, showing that the Eledones actually attack the bait.

During the winter Eledone leaves the shallow water, round the South coast of Devonshire, and seeks the warmer and deeper water in the centre of the channel. Specimens taken in this season, from deep water, generally die before the trawlers get back, probably from cold. With the warmer months Eledone comes further in, and so from May to September it is taken in Plymouth Sound, at an average depth of eight fathoms; and in a hot summer it is unusually abundant. Sometimes it is found stranded at low tide, in the rock pools on various parts of the coast. Curiously enough, the Eledones obtained are almost always females. The relative abundance of the sexes appears to be fifty females to one male. This disparity in proportion is also noticeable to a greater or less degree in all Cephalopods. Possibly the males, besides being fewer in number, remain in deeper water, the females alone coming in with the warmer weather to spawn, or, again, the males may have a different method of concealment.

HABITS.

Eledone cannot be called an active animal. When kept in a tank, if undisturbed, it passes most of its time resting. Its attitude is often, as Text fig. I shows, with the arms bent at an acute angle to the body, and adhering to the floor of the tank by the suckers on the proximal regions of the arms. The visceral dome also rests postero-ventrally on the ground, and the eyes are more or less closed. At other times it rests with the tentacles folded together so as to form an oval disc of attachment by which it clings to the wall of the tank, the body hanging downwards in the water.

When disturbed, Eledone seeks to escape by swimming rapidly backwards, the motion being obtained by ejecting powerful jets of water forward from the anterior opening of the funnel. When swimming, the arms are stretched out horizontally in a straight line with the rest of the body, while the visceral dome points forwards. The eight arms lie closely together, and looking down on the animal from above, six arms may be seen. Of these the outermost pair (II ventral) are curved outwardly in the middle region. Thus Eledone does not use the web when swimming, but only when sinking downwards through the water. Then the tips of the arms separate radially like the ribs of an umbrella, so as to stretch out the triangular pieces of web between the arms.

Eledone has another mode of progression—creeping. This it does with a gliding motion, sometimes slowly, at other times more rapidly—particularly when in pursuit of food. When creeping, the body is raised from the floor of the tank, and the animal advances somewhat in the posture of the Text fig. I, creeping by means of the suckers on the middle region of the arms. Sometimes the suckers further down are used, and consequently the body is raised higher, while the animal appears to advance on tip-toe. Eledone generally creeps thus when stalking prey. Often when creeping up the wall of the tank, the arms are well separated, so that the web is half extended. Apparently, Eledone only swims when seeking to escape. Possibly when not in captivity it may have nocturnal periods of activity, when swimming takes place. Careful watching of active specimens has not, however, revealed this habit, but that may be explained, perhaps, as due to artificial conditions.

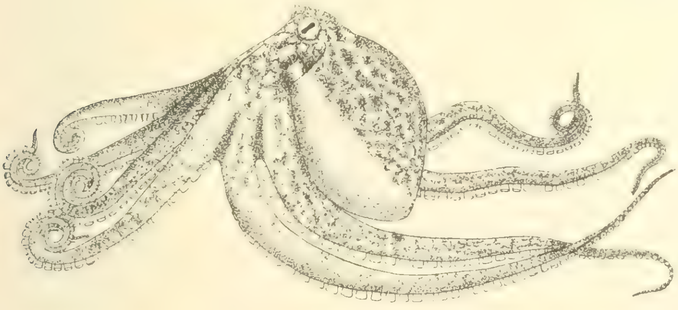

FIG. I.—*Eledone cirrosa*, at rest.

During the night Eledones will sometimes escape by climbing over the walls, if in an uncovered tank.

The shape of the visceral dome varies considerably. When resting, the body is shortish, and forms a bluntly rounded stout sac, and the arms may be coiled up or stretched out and are often waved gently about; while at other times they are passed over the surface of the body, seeming to brush it, or are passed down into the mantle cavity and then out again. When swimming, however, the shape of the body alters. It becomes stretched out antero-posteriorly, and so assumes a form very like that of *Sepia*, while a lateral fold of skin becomes prominent, which marks off the dorsal from the ventral surface, and forms a delicate fin, very similar again to that found in *Sepia*. Wave-like undulations, beginning at the front and passing backward, pass along this temporary balancing organ, which helps to support the body. With the return to rest or creeping the fin is lost again, becoming indistinguishable from the general body surface. Also when swimming, a longitudinal median depression on the ventral surface of the mantle indicates the line of insertion of the vertical septum, on its inner surface.

Eledone is often found in the morning adhering halfway up the glass front of the tank, nearest the light. At other times it hides in dark corners, and if stones are provided, will heap these into a rough mound in a corner of the tank and hide behind this. It was, no doubt, this desire for dim seclusion that often led one to rest with the cephalopedal mass inside a jam jar, which was in one corner of the tank. Eledone, apparently, dislikes a strong light, in which it seems quite incapable of opening its eyes. If a light is brought near during the night, the eye contracts and the animal retreats.

How long Eledone lives is not known. However, from the fact that during the early spring quite young specimens occur—probably hatched from the previous summer's spawn together with many stages between half and full grown specimens, they probably live several years under natural conditions. At present nothing is known as to their rate of growth, or the size at which sexual maturity is reached. Eledone is an extremely delicate animal, and rapidly suffers if the tank in which it is placed has not a good and constant supply of sea water. Hence it is practically impossible to observe it alive elsewhere than at the Marine Biological stations. Confinement affects it in various ways. For instance, although it was found, on dissecting several Eledones which had been kept in captivity for some weeks, that the ink sac was full of ink; yet after the violent ejection of ink which occurred when the animals were first caught, and one or two very slight subsequent discharges, no ink was ever again poured out. Even when being killed, no ink was ejected, although the body was convulsed, and the animal appeared to make a great effort to discharge the secretion.

FOOD.

As Eledone is taken in both crab and lobster pots, probably it eats both these Crustaceans. However, when kept in tanks, it is generally fed on crabs, and crab remains alone were found in the gut of numerous specimens which were examined. It has been known to attack and devour the Norway lobster, and will take prawns or shrimps when they are placed in the same tank. Preferably it takes the Edible Crab, *Cancer pagurus*, but *Portunus depurator* is also taken, and *Carcinus moenas*. Eledone sometimes stalks its food, creeping after the scuttling crabs in the posture previously described. With a quick rush it generally reaches its prey and renders it incapable of motion by spreading its arms over the crab. Sometimes it gathers up several crabs simultaneously in this way—taking an armful as it were. These are then consumed one by one. At other times it secures its prey by quickly swooping down upon it from the water above, with the arms outstretched.

How, exactly, Eledone opens the crab cannot be seen, as the arms cover over and so hide the prey from view when it is being consumed. If, however, the dorsal carapace is removed from a crab in the easiest way possible, beginning at the posterior edge, and simply pulling the shell away, the portion which comes away is exactly similar in shape to that which Eledone leaves. Hence probably it adopts this method of removing the carapace with its beak, and then eats the soft body of the crab. Usually the ventral exoskeleton and limbs of the victim are left attached to one another, or the limbs may be broken away. While feeding, Eledone curls its arms about in the water, as though with pleasurable excitement. No accurate observations have been made as to the amount of food consumed in any given time. They have been known to attack and eat one another, the arms only of the victim, which is not necessarily killed, being generally devoured. Only two records have been made of the occurrence of *E. cirrosa* in the stomach of British fish (the Angler and the Ling—see list below). It is not improbable that dolphins and porpoises prey on the large Eledones, while the young and therefore small and feeble ones probably form food for various marine animals. When they attain some size, the suckers and beak will render them decidedly uninviting. Possibly their sinister attitude and bright colour also protect them. Congers will take pieces of the flesh when given as food, but other fish refuse it altogether. Crabs will take it as food only reluctantly, although they will readily eat weak or dead Sepia.

Cephalopods have been recorded as follows from the stomachs of British fishes:—

Loligo, in Cod, Whiting, Gurnard, Plaice, Skate.
Octopus, in Haddock, Ling, Whiting, Plaice.
Eledone, in Ling and Angler. (Two isolated cases only.)
Rossia, in Haddock, Whiting, Cod, Gurnard, Dab, and Long Rough Dab.
Sepiola, in Whiting, Cod, Gurnard, Tope, Thornback, Dab, and Pout.

EXTERNAL FEATURES.

I.—Skin.

The skin of Eledone has a smooth external surface. It is soft and slimy to the touch, and contains numerous gland cells. These secrete an opaline mucus, which is especially noticed while killing the animal, say, with chloroform, when the body becomes coated with this secretion. It is, however, by no means as thick or sticky or as abundant as that secreted by *Archidoris*, or the common garden slugs, under similar conditions. In appearance the skin is smooth and velvety, and reminds one of a peach. It is also tough and elastic. When Eledone is quiet it may be noticed that the skin is finely granulated all over the body. In addition to these granulations, there are also larger conical processes or cirri, on the head and back, of 6 to 12 mm. in height.

On the head there is a single pair of these cirri, which remind one of slight horns, over the eyes (Pl. I, fig. 1, *l.d.c.*), and down the back there are about seven rather irregular rows of five or six papillae. However, when Eledone is agitated or moving about, the skin appears to become tightened over the surface of the body, and this stretching causes the granules and cirri to flatten down, and become indistinguishable from the rest of the surface. After a short period of rest, the slackening of the skin causes the granules and cirri to reappear. These processes are not visible after death, and so a true idea of the skin of Eledone can only be gained by watching the living animal.

The colouration of the body is due to the chromatophores which lie in the dermis, and are only absent from (1) the oral surface of the web, and (2) the suckers and the oral surface of the basal parts of the arms. Hence these parts are white, but when the web is stretched open, the chromatophores on its aboral side may be seen through as greenish dots, by transparency. The following notes were made as to the colouration of Eledones kept in the tanks of the Plymouth aquarium, when undisturbed.

1. Lower or ventral aboral surface of web light buff, with a pale green metallic tinge.

2. Dorsal aboral surface of web buff mainly, with flecks of cream scattered in between the predominating patches of buff; aboral surface of arms similar.

3. Funnel light and practically colourless posteriorly, with yellowish-brown colouration anteriorly. The colour is deeper on the dorsal than on the ventral surface of the funnel, where there is also some indication of the metallic green tinge which is found on the ventral surface of the web, and of the mantle sac.

4. On the ventral surface of the mantle sac the brownish chromatophores are larger than in other parts of the mantle, and situated further apart. The prevailing colour here is white, with a light, metallic green cast.

5. The dorsal surface of the visceral dome, like that of the web and head, shows patches of cream in between large flecks of a reddish-buff colour. From the eyes two oblique lines of cream colour slant inwards and meet, forming a light-coloured **V** on the dorsal surface of the head. The iris of the eye is deep orange in colour. The chromatophores are continued over the free edge of the mantle, for about half an inch inside the pallial cavity. The marbling of the skin is most distinct when the animal is recovering from excitement. When quiet the cream and buff flecks fade into one another rather indistinctly, while the intense blush caused by excitement spreads all over the skin and temporarily eliminates the marbling, but when recovering again, the cream flecks show up well against the terra-cotta patches. When the animal is excited the skin becomes of a very dark reddish terra-cotta tinge. After death the eyes become dull, and the skin loses its velvety gloss and beautiful colouration utterly, and becomes overcast with a dull grey tinge. When Eledone is frightened in any way, the skin changes colour, and an intense pallor spreads over it, causing it to become quite ghostly in appearance. At this time the eye stands out very prominently, because the iris remains dark orange, as does the eyelid surrounding it, and thus an orange circular patch marks out the eye, on a whitened body. However, under normal conditions this patch does not stand out in any way. At the same time that the pallor is seen the animal tries to escape by rapidly swimming backwards, and attempts to eject ink. Almost immediately the pallor is replaced by an intense

darkening or blush of deep terra-cotta colour over the whole body. If allowed to come to rest again now, the colour gradually lightens until the normal condition is reached. If the animal is stimulated several times in succession—say by poking with a glass rod, or by bringing a brightly coloured bottle near—it becomes exhausted, the pallor becomes less intense, and the consequent darkening less noticeable; also efforts to escape cease. At night the colour is like that of the resting condition.

Structure of the Skin.—The skin consists of a columnar epidermis, and a subjacent and much thicker dermis (Text fig. II). It may easily be detached from the muscular body wall, thus destroying the deeper layers of the dermis. The epidermal cells secrete a thin cuticular protective layer externally, while internally they are each produced into several fine processes which attach the epidermis closely to the dermis.

The dermis is divisible into four layers, as follows:—

1. External fibrous layer (Text fig. II, *Ex.C.L.*).
2. Layer with chromatophores (Text fig. II, *Chr.*).
3. Layer containing iridocysts (Text fig. II, *Irid.*).
4. Internal fibrous layer. This is the thickest layer, and connects the skin to the underlying muscles of the body wall. It contains the vessels and nerves of the skin, and also feeble muscular strands (Text fig. II, *I.C.L.*).

Chromatophores.—These are extensible pigment-containing vesicles, occurring in the external part of the dermis (Text fig. II, *Chr.*). Their expansion and contraction cause the changes of colour so characteristic of all Dibranchiate Cephalopoda. The origin, structure and movements of the vesicles have been studied by many people, and much variation of opinion exists on all three points. The views of Rabl, Müller, Klemensiewicz, Frédéricq and Kolliker may be briefly summarised thus:

1. The central spherical cell, which contains pigment granules, is a uninucleate cell which originates in the epidermis and later sinks down into the dermis. The cell wall is a tough elastic membrane, and the pigment granules are arranged round the periphery of the cell, leaving the central protoplasm clear.

2. A girdle of about 18 mesodermal cells becomes grouped round the equatorial region of the pigmented cell, in a plane parallel to the epidermis. These cells finally become differentiated into triangular muscular bands of fibrous tissue, the basal side of the triangle adhering to the wall of the vesicle, and the long thin apical region being lost amid the surrounding tissue of the dermis. A basal nucleus shows in each fibre.

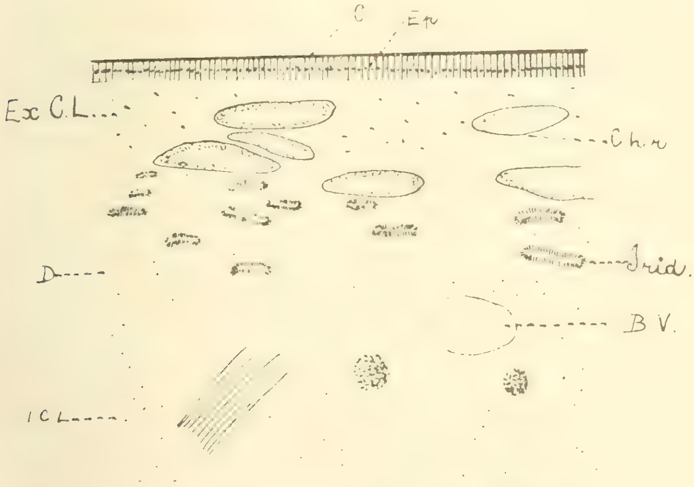

Fig. II.—Section of the skin. Highly magnified.

3. The elasticity of the vesicle wall opposes the contractile tendency of the radial fibres. When the latter contract, and the wall relaxes, the vesicle becomes stretched out and flattened in a plane parallel to the

epidermis. When the chromatophores are thus expanded, the colour of the animal is very deep—this occurs when Eledone is excited in some way. When the radial muscles relax, the chromatophore contracts and the animal becomes pale, as when frightened. In the normally quiet state the chromatophore is in a state of tension, and is shaped like a biconvex disc (II, *Chr.*). In this stage it is in a semi-expanded condition, the contractile tendency of the two elements being equally balanced. However, the cell is constantly varying slightly in shape, as one or the other of the forces gets the upper hand; and so the chromatophore exhibits incessant slight tremulous movements. Hence when watching Eledone in an aquarium, one is struck by the constantly varying colour of the skin.

Harting, Blanchard and Girod agree that the vesicle is of ectodermal, and the girdle of mesodermal origin, but they consider that all motion on the part of the chromatophore is due to the amoeboid movements of the vesicle itself, while the radial fibres are connective tissue only.

Again Chun, who worked on the chromatophores of *Bolitaena*, a deep sea form, disagrees with both these views. In *Bolitaena* the chromatophore arises as a single ectodermal cell which sinks down into the dermis. The nucleus now divides repeatedly, while the cell throws out about 18 pseudopodial processes, in the equatorial plane parallel to the epidermis. At the base of each process is found a corresponding nucleus, which has originated as above. Later it is found that this girdle of processes has become differentiated into a ring of triangular muscular strands, whose contraction serves to expand the chromatophore. A second muscular region becomes differentiated round the periphery of the cell, and this opposes the radial tracks, tending to contract the chromatophore. Hence Chun in *Bolitaena* derives the vesicle and the contractile apparatus wholly from one ectodermal cell. He has also traced the nerve supply of the chromatophores. For instance, the pallial nerve has several purely chromato-motor strands which run outwards to the external epithelium of the mantle, and there divide up ultimately into fine terminal nerves, one of which supplies each radial muscular strand, entering it at the narrow distal end. These nerves control the movements of the chromatophores, and therefore if the pallial nerve be severed the movements of the chromatophores on the corresponding side of the mantle cease. This method of origin, which Chun has described, may be peculiar to the chromatophores of *Bolitaena*, and is difficult to reconcile with the account given by Rabl and others.

In Eledone the pigment granules are very minute and of a reddish-buff colour. As in all Cephalopods, the motion of the chromatophores continues some time after death.

Iridocysts.—These are light-reflecting cells embedded in the dermis below the chromatophore layer. They are uninucleate flattened cells, each of which contains two rows of thin fibrillar laminae arranged parallel to one another and reflecting the light, and so giving rise to the peculiar metallic iridescence noticed in the integument.

II.—External Organisation.

The body may be divided into two regions—an anterior *cephalopedal mass*, and a posterior mass, or *visceral dome*, covered by the mantle.

As in other Octopoda these two regions are united dorsally by a thin superficial sheet of muscles. Externally the two regions of the body cannot be definitely marked off, but merge gradually into one another. When touched with the hand, the body feels soft and slimy and of about the consistency of a firm jelly. The flesh retains its elasticity for some hours after death. The following are the dimensions of a probably full-grown Eledone, immediately after death:—

Length of arm	360 mm.
Length of visceral dome	160 mm.
Length of head	38 mm.
Total length	558 mm.
Width of head	75 mm.
Width of body at widest part ...	140 mm.

(A) **Cephalopedal Mass.**—This mass, which forms the greater part of the body of Eledone, as regards length, consists, as the name implies, of the head and foot.

(1) **Head.**—The head is a solid oval mass, behind the arms and anterior to the visceral dome. The anterior part or buccal mass is hidden away inside the bases of the arms, and hence only the posterior portion shows externally. Laterally it bears the eyes, while the central portion consists of the muscles which cover the brain cartilage, ventrally and dorsally. To the ventral surface of the head is attached the funnel (Pl. III, fig. 11, *F.*).

Cephalic Cartilage.—It is convenient to describe the structure of the Cephalic and Orbital Cartilage here. They are both built up of oval cells surrounded by a clear matrix (Pl. VI, fig. 66*a*, *C. cell* and *Matr.*). These cells have large oval nuclei, and are connected by fine cytoplasmic processes one with another. Hence the spaces occupied by the cartilage cells also intercommunicate by canals down which these cell processes run.

(2) **The Foot** is divided into eight equal muscular processes, or arms. In the female these are all similar, but in the male the third right arm is hectocotylised

counting ventrally from the dorsal surface. The arms are long, flexible tapering cones, slightly compressed laterally, and closely connected at their bases, to form a circular circumoral crown round the Buccal Mass (Pl. I, fig. 1, *Br. app.*). The bases of the arms are connected by a membranous semi-transparent web which extends for about one-fifth of the length of the arm, as an inter-brachial membrane. Further along it is continued as lateral wings—one on each side of each arm—which gradually diminish in size, and towards the distal end of the arm can no longer be distinguished (Pl. I, fig. 1, *W.*). This web is characteristic of the family Octopodidae, to which Octopus and Eledone both belong. Measuring the two dorsal arms and the body of half a dozen specimens of Eledone, it is found that the relative length of the arm, to the head and body, is 229 mm. to 113 mm. or roughly 2 to 1. There are about eighty suckers on each arm, arranged in a single row. They have no horny ring, and thus differ from the suckers in the Decapoda. Also they are much shallower, and none are modified into hooks. The suckers in Eledone are sessile, but the surface of the arm which supports them is raised up beneath each sucker into a flexible cylinder which really acts as a stalk, and allows it to move freely about. Successive suckers are separated from one another by a slight space. It is noticeable that when these suckers are applied to any surface, they do not keep in one straight row, but become displaced laterally so as to give the effect of several irregular rows of suckers on the arm. The sucker nearest to the movth is about 3 mm. in diameter in a large specimen, and equals in size those about half-way down the arm. At first they increase in size working from the mouth towards the tip of the arm, and the fifth and sixth suckers are the largest which occur—about 12 mm. to

18 mm. in diameter. From here they steadily decrease again, towards the tip becoming almost too small for the naked eye to distinguish. The pressure they exert is very great, and must render the prey completely helpless. Even when only clinging to the hand with one tentacle, Eledone can hold on firmly enough by sucker action to enable one to lift the creature bodily out of the water. Frequently the skin is shed from the surface of application of the sucker.

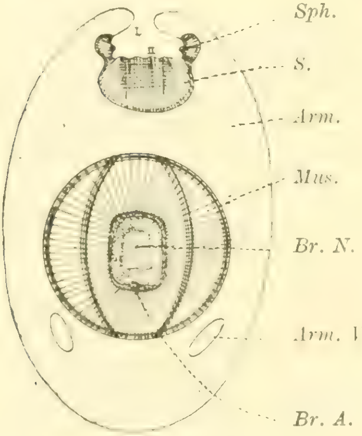

FIG. IIIa.

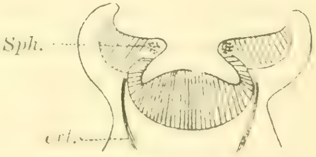

FIG. IIIb.

FIG. III (*a*) Trans. sect. distal part of arm showing relation of sucker (*S*).

FIG. III (*b*) Sagittal sect. of sucker of *Argonauta*.

Text fig. III *a*, shows a diagram of a transverse section through the arm, indicating the relation of the sucker to the remaining muscles. III *b*, is a modification of Niemiec's figure of the sucker of *Argonauta*. The outer surface of the sucker is covered by the general skin of the arm. The inner lining is a much folded epithelium, which covers the inner and outer divisions of the adhesive cup (III *a*, II and I). A sphincter muscle (*Sph.*) tends to close the upper and lower cups off from one another, and this muscle is opposed by the vertical extensor muscle (III *b*, *ext.*). When the sucker is applied to any object, the extensor relaxes, the sphincter contracts, and the massive muscular base of the inner chamber is elevated to meet the sphincter. Thus we have a shallow flattened disc-like surface pressed closely against the object to be held. Now the extensor contracts and the sphincter relaxes a little, and the floor of the inner chamber is drawn away from the object, producing the desired vacuum.

All Cephalopods have power to regenerate injured arms. Frequently specimens of Eledone have been seen with several arms in process of regeneration. When an arm is first injured, it is curled up spirally towards the mouth so as to protect the injured part.

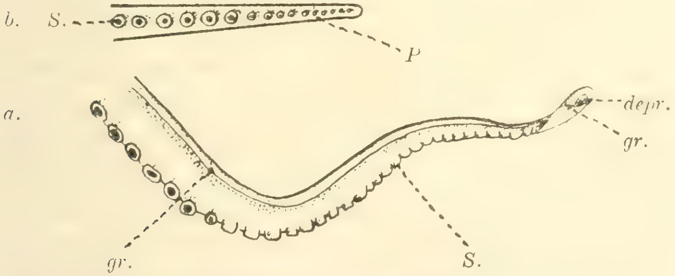

FIG. IV.—(*a*) Hectocotylised arm and (*b*) ordinary arm of male *E. aldrovandi*. x 2.

Hectocotylisation.—The third right arm of the male Eledone is hectocotylised, i.e., it is modified for the purpose of transferring the spermatophores expelled from the anterior opening of the funnel into the oviduct of the female. As no male *E. cirrosa* could be obtained, Text fig. IV *a*, shows the hectocotylised arm of a young male *E. aldrovandi*, which is very similar. Some Cephalopods have an autotomous hectocotylised arm, e.g. *Argonauta* and *Tremoctopus*, and in these hectocotylisation reaches its extreme state of specialisation. Spermatophores having been expelled from the funnel of the male, are stored in this arm, which, when packed with them, becomes detached and in some way enters the mantle cavity of the female. The arm of Eledone, however, is less specialised and not autotomous, and the chief modification is at the tip, as in *Octopus*. Probably then the tip of this arm is inserted in the terminal part of the oviduct of the female, after the manner actually watched and figured by Racovitza in the case of Octopus. The hectocotylised arm of Eledone is somewhat shorter than the others—about 13 mm. less in the small specimen examined of *E. aldrovandi*. Examining the ventral surface, it may be seen that the third right arm—counting ventrally from the dorsal pair—bears a groove on its ventral aspect (IV, *gr.*). This is formed by a narrow fold of skin, and runs from the base to the tip of the arm, where the groove is enlarged to form an oval depression on the oral surface of the arm tip (IV, *depr.*). Moreover, the other seven arms of the genus Eledone are somewhat modified in the male. The suckers at the tip are set more closely together than in the female, and are shallower (IV *b*, *S*). The sixth and seventh suckers from the tip have practically no cavity at all, and the remaining ones are represented by tiny flat pads (IV *b*, *P*).

(B) **Visceral dome.**—This is the name given to the mass formed by the principal viscera of the body. Externally it is enclosed by the thick muscular mantle. It is oval in shape, being longer than it is broad, and bluntly rounded posteriorly. Anteriorly the visceral dome is marked off from the head by a slight constriction or neck. The dorsal surface is more convex than the ventral, and lies uppermost during creeping and swimming. As the shell is greatly reduced in Eledone, the visceral dome is unprotected save by the skin and muscular mantle.

MANTLE.

The mantle encloses the visceral mass, forming a sac with thick muscular walls, which extends from the posterior end of the body as far as the posterior border of the head dorsally and of the funnel ventrally (Pl. I, fig. 1; Pl. II, fig. 8; M_1). Morphologically it is an outgrowth of the posterior part of the visceral envelope, and hence its inner wall is continuous with the outer wall of the visceral sac. The space between these two walls is the mantle cavity. The anterior edge of this sac is fused with the head dorsally, but ventrally and laterally it is free, so that a wide entrance to the mantle cavity is thus left.

The Mantle Cavity may best be studied by cutting the mantle down from the free edge on each side of the mid ventral line, so as to expose the organs contained therein. It is a deep cavity, as in Sepia and most Cephalopods, and is more spacious ventrally and laterally than dorsally, in order to enclose the important pallial complex. The body is bound to the enveloping mantle by: (1) The above-mentioned dorsal fusion of head and mantle; (2) the shallow siphono-pallial articulation; (3) a vertical muscular septum running out from the median ventral line of the inner surface of the mantle to the visceral mass and dividing the mantle cavity into symmetrical halves; (4) the posterior continuity of the inner surface of the mantle with the external epithelium of the visceral mass; (5) two pairs of muscular bands running out from the afferent and efferent axes respectively of the gills—the band running along the outer surface of the efferent vessel is inserted on the inner ventral surface of the mantle, posterior to the insertion of the vertical septum, and that running along the inner edge of the afferent vessel is inserted on the upper end of the mantle cartilage, near the insertion of the funnel retractor; (6) the depressor muscle of the funnel, running out from the funnel to the mantle, near the branchial heart (fig. 8, *F.D.*); and (7) the great lateral muscle running out from the cephalopedal mass to the mantle (fig. 8, *L.M.*).

The epithelium lining the mantle cavity is the internal continuation, over the free border of the mantle, of the outer skin of this structure, which here becomes much thinner and loses its chromatophores, and hence is transparent and colourless. However, the epithelium covering the dorsal side of the visceral sac bears large chromatophores, which show through the mantle during life on account of the transparency of this structure.

Stylets.—On removing the genital gland and the posterior portion of the alimentary canal, the dorsal portion of the mantle is exposed, internally. Two curved tracks can be seen, roughly forming a **V**-shape, posterior to the depressors of the funnel (Pl. III, fig. 13). By dissecting away these muscles, and the great lateral muscles, just at their bases, and then removing the inner epithelium of the mantle, two colourless, semi-transparent rods are exposed (Pl. III, fig. 13, *C.S.*). These are chitinous rods, oval in section and tapering at both ends, which reach down almost to the posterior end of the mantle, and are embedded in its substance (Pl. III, fig. 16, *a* and *b*). At the point of insertion of the funnel depressor the rods are thickest. Pl. III, fig. 15, represents a transverse section through the stylet, *in situ* in the mantle. Each stylet is enclosed in and secreted by the walls of an epithelial sac, one cell thick only. These cells are columnar, and are rather longer at the two ends of the sac than in the central region (fig. 15, *Ep.S.*). This figure also shows that the rods are built up of concentric layers of chitin, the innermost, and therefore oldest, layers staining most deeply. Among the chitinous layers may be noticed a few cells with deeply staining nuclei. These are probably degenerate cells from the epithelial sac, which have become surrounded by chitin. Round the sac is a layer of connective tissue, outside which can be seen the muscles of the mantle (fig. 15, $M_1M.$). According to Appellöf, the epithelial sacs in Octopus, and therefore probably in Eledone, are formed by the shell gland. This gland, after closing and sinking below the external surface of the mantle, divides into two halves, each of which takes up a lateral position and secretes the stylet of its side. Hence these stylets represent the shell in Eledone, i.e., they are the homologues of the shell of other Mollusca, although much reduced in size and importance. The fact that the great muscles of the funnel, cephalopedal mass, and the muscles of the mantle radiate from these stylets, also gives support to this view. Possibly this degeneration of the shell in Eledone, as in other Octopoda, may be explained by the fact that it is no longer needed as a means of protection. For we must recognise that the means of offence and defence that Eledone still has are most efficient—powerful suckers, great biting jaws, immense bodily strength, together with the ink sac and large far-seeing eyes.

Dorsal fusion of head and mantle.—In the Decapoda the head and visceral dome are not as a general rule united dorsally. However, in Sepiola there is a narrow connection between the two. Eledone, like Octopus, shows this dorsal fusion in a more complete stage. A thin sheet of muscle is continued anteriorly from the dorsal edge of the mantle over the region of the eyes, and fuses with the muscular bases of the arms, thus forming a firm dorsal union between the head and visceral dome.

Siphono-pallial articulation.—This is very weak in Eledone, as in all Octopoda. It consists of two shallow ridges on the postero-ventral edge of the funnel, which fit in two corresponding shallow grooves of the anterior and inner ventral surface of the mantle (Pl. II, fig. 9*a*, *l.f.r.*, *l.m.gr.*).

Vertical muscular septum. This consists of two symmetrical triangular sheets of muscle, which run out from the mantle to the body and enclose the anus between their anterior edges (Pl. II, fig. 8; Pl. III, fig. 11, *m.s.*, $m_1 s_1$ and *an.*). The septum is covered by the general epithelium of the mantle cavity. The shortest side of each sheet is anterior, while the longest runs from the base of the mantle out obliquely to the visceral mass. The vertical line of attachment of the septum extends from the ventral posterior extremity of the mantle to within half an inch of its anterior edge (figs. 8 and 11, *m.s.a.*). By referring to fig. 11 it will be seen that after the septum enters the mantle cavity (*e.m.*), it is free for some distance from the visceral mass, and hence adheres only to the mantle. About half-way up the length of the oviduct, it becomes attached to the visceral mass. Hence there is free communication, posteriorly, between the right and left halves of the mantle cavity (fig 11, *P.C.*). Each of the two halves of the septum consists of two rather thin sheets of muscle—(1) an upper sheet sloping from the mantle, obliquely inwards and downwards, to the body (figs. 8 and 11, m_1); and (2) a lower sheet sloping from the mantle, obliquely inwards and upwards, to the body (figs. 8 and 11, *m.p.*).

The lower strands of the upper sheet and the outer strands of the lower sheet run towards one another, and form a superficial sheet which runs along with the funnel retractor muscle, down to the mantle (fig. 11, *m.l.*, *m.p.* (*x.*, *F.D.*). The upper strands of the upper sheet, and the inner strands of the lower sheet, after a superficial course run together, and sinking deeper join in with the great lateral muscle.

Muscles attaching gills to mantle.—The narrow muscular band which runs along the external surface of the efferent vessel of the gill, from the tip downwards, after leaving this artery at the base of the gill, runs obliquely inwards over the ventral surface of the kidney to meet its fellow in the middle line (Pl. V, fig. 37, *Br.M.*). The common strand now runs posteriorly, over the ventral surface of the genital capsule, and is inserted on the inner face of the mantle, just posterior to the vertical septum. Possibly this strand affords additional support to the genital gland, when it is enlarged at the time of sexual activity, as well as serving to deflect the gill.

FUNNEL.

This may well be studied along with the mantle cavity, as it is closely related thereto. It is a hollow conical structure, truncated anteriorly (Pl. II, fig. 8, *F.*), which is attached to the ventral surface of the head, and is free laterally and ventrally, and for about the anterior third of its dorsal wall (fig. 11, *F.*). The anterior and external opening of the funnel is about 13 mm. in diameter, in a large specimen, while the posterior internal opening is very much larger and forms the base of the cone. At the posterior end, the ventral edge of the funnel is recurved, ventrally and anteriorly. This forms a ridge, which is more pronounced at the sides than in the centre, and forms part of the funnel articulation (Pl. II, fig. 9*a*, *l.f.r.*). The weak locking apparatus is in strong contrast with the firm one found in *Sepia*, *Loligo* and other Decapods, and this means of locking the mantle seems to have weakened as the dorsal fusion formed, and so rendered it less necessary. Also, as Eledone is a much less powerful swimmer than the Decapods, the need of a strong funnel articulation is lessened. The funnel cavity is three-chambered. The central largest chamber alone opens to the exterior, while the lateral chambers are blind anteriorly. All three, however, open into the mantle cavity. The central chamber is cut off laterally from the side chambers by the great depressor or retractor muscle of the funnel. This forms the ventral and ventro-lateral wall of its own side of the funnel, and then runs out to its insertion on the anterior border of the mantle cartilage of its side. Two other pairs of muscular bands, which are narrow and rather short, run in from the dorsal surface of the funnel to the cephalopedal mass. They act as protractors of the funnel, and are exposed by cutting through the skin behind the funnel, as in Pl. II, fig. 9, *sk.*, and turning the funnel ventrally. The protractors form a letter **W**, the external pair being inserted above the inner pair, on the funnel wall. The external pair run outwards and dorsally, to join in with the capito-pedal muscles just below the eyes. The internal pair run inwards to the ventral surface of the cranial cartilage, and are attached there. The dorsal wall of the funnel is formed by a broad pair of muscles which then run outwards from the posterior lateral region of the funnel to the top of the mantle. Thus with the depressor, these two nuchal or collar muscles bound the lateral funnel chamber. Hence the funnel muscles are arranged in three sets:

(*a*) One pair of depressors (fig. 9*a*,, *F.D.*),

(*b*) One pair of nuchal muscles (fig. 9, *coll.*), and

(*c*) Two pairs of protractors (fig. 9, *L.F.Pr.*, $L.F.Pr_1$).

From the above description it can be seen that, although water may enter the mantle cavity all along the external opening of the mantle, yet when the funnel is locked the only way out for the contents of the mantle cavity—excretory or genital products, water, &c.—is through the central funnel chamber. As in other Octopods, Eledone has no valve in the funnel. It has, however, a large and elaborate mucous gland—Müller's gland (Pl. II, fig. 10, *f.o.*). This is four-lobed, and is an elaboration of the internal epithelium of the funnel, and may best be seen by opening the funnel ventrally, as in Pl. II, fig. 15. It serves to lubricate the internal surface of the funnel, which consequently is generally coated over with opaline viscous mucus, rendering the gland itself rather obscure in fresh specimens. It may be seen, however, on scraping the mucus away.

Pallial Complex (figs. 8 and 11).—Under this general term may be included those important organs situated in the mantle cavity, together with the external apertures of certain internal organs. Eledone, like other Cephalopods, in spite of its high specialisation along certain lines, has yet retained its primitive symmetry in certain features, including the pallial complex. The organs of the pallial complex are:—

(1) A pair of **Gills**, one on each side of the visceral mass, and attached to it by muscles, vessels, &c. (fig. 11, *g.*);

(2) The **Anus**, situated anteriorly, between the left and right halves of the vertical septum (fig. 11, *an.*);

(3) The **Urinary papillae**—one pair, protruding for about 12 mm. in a large specimen into the mantle cavity, just in the angle between the base of the gill and the visceral mass (fig. 11, *Ur. p.*). The urinary aperture is a small hole at the tip of this papilla;

(4) **Genital ducts.** In the female these are a pair of equally developed oviducts, which may be seen running below the visceral epithelium from the urinary papilla upwards for 12 to 24 mm., according to the size of the specimen. The tip of the oviduct is alone free, and protrudes for a short distance out from the visceral mass into the mantle cavity, bearing the oviducal aperture at its end, somewhat below the anterior end of the gill (fig. 11, *od. ap.*). In the male (fig. 8), there is a single genital duct—the penis—situated similarly to the left oviduct in the female (*pen.*).

Other organs exposed on opening the mantle cavity. After removing the vertical septum the following are seen :—

(1) The intestine, running vertically up in the median line, over the liver to the anus, with the anterior vena cava lying on its left side;

(2) The ventral surface of the liver, covered by the visceral envelope; and

(3) The two kidney sacs, posterior to the liver.

Visceral envelope. On removing the epithelium and the septal muscle, which envelop the visceral mass of Eledone, a muscular envelope external to this visceral mass is exposed. Over it ventrally run the visceral nerves (Pl. IX, fig. 69, *Visc.N.*). This envelope, dorsally, runs from the posterior border of the cerebral cartilage, to which it is attached, down to the level of the branchial hearts, where it becomes adherent to the muscular mantle. The dorsal region of the envelope is stouter than the ventral, and contains large widely separated chromatophores, which probably show through the mantle during life. The thin ventral region covers over the liver and ink sac, but is dorsal to the rectum. It runs back from the ventral posterior edge of the cranial cartilage to the anterior edge of the posterior division of the great venous sinus (Pl. VII, fig. 53, S_3V_3), to the wall of which it is attached by connective tissue. Ventrolaterally the envelope is reinforced by the depressor muscles of the funnel. Dorsolaterally it is similarly strengthened by the great lateral cephalopedal muscles.

General conclusions.—Considering Eledone as a type of the Cephalopod organisation, the following characters are noticed:—

1. It retains the primitive bilateral symmetry of the Phylum, and hence in this respect is less specialised than many Gastropods such as Helix.

2. On comparison with more primitive members of the Phylum, e.g. Chiton, it is seen that profound changes have evidently occurred in the inter-relations of the head, foot and visceral dome. The alimentary canal has turned forward posteriorly, so becoming **U**-shaped. The anus has been ventrally approximated to the mouth, the free ends of the gills point anteriorly, the true morphologically ventral surface of the body has been greatly abbreviated, and the dorsal correspondingly lengthened. The mantle now has the form of a pouch or sac, enclosing the visceral dome. Simultaneously with these changes the foot ceased to be used merely as a ventral creeping organ, and was transformed into a circumoral mass. Probably this was effected by the lateral regions of the foot growing up dorsally, on each side of the head, and finally fusing above it, the anterior edge meanwhile growing out into long flexible processes.

DIGESTIVE SYSTEM.

The following is the best method of dissecting out the alimentary canal:—

1. Remove the funnel from the ventral surface of the head.

2. Cut down the web between the two ventral arms, beginning anteriorly, and continue the cut down along the ventral surface of the head, thus exposing the Buccal bulb and the cartilage surrounding the brain.

3. Loosen the intestine from the liver, dissecting out the ink sac from its place on the latter, so as to enable the intestine to be turned back.

4. Loosen the liver at the sides, where it is connected to the cephalopedal muscles, by cutting through the visceral envelope, and then turn the liver forwards (Pl. V, fig. 38*a*). The organs enclosed in the visceral sac are now exposed. Pl. IV, fig. 17, represents the alimentary canal, entirely dissected away from the surrounding tissues, to give a clear representation of the relations of the various parts. The alimentary canal is essentially a **U**-shaped tube, the ventral limb of the **U** being the shorter, and the anus being approximated to the mouth.

The Mouth is situated in the centre of the oral and anterior surface of the arms (Pl. II, fig. 5). It is circular, about 12 mm. to 22 mm. in diameter in large specimens, and is surrounded by a circular lip the edge of which is furnished with short finger-like papillae (Pl. IV, fig. 17, *m.*; Pl. II, fig. 6, *l.*). The external surface of the lip is continuous with that of the web, and only marked off from it by a deep groove (fig. 6, gr_1). This edge of the web forms a kind of contractile outer lip. The mouth leads into a cavity with very thick and muscular walls. This is the **Pharynx** and the oval muscular mass enclosing it is known as the **Buccal Mass** (fig. 17, *B.M.*). The buccal mass is surrounded, and therefore concealed, by the muscular bases of the arms (Pl. III, fig. 14, *B.M.*, *arm*). The pharynx is furnished with two powerful chitinous jaws, whose shape curiously resembles that of a parrot's beak, and which are placed dorsally and ventrally. Unlike the parrot, however, the ventral jaw of Eledone, which bites outside the dorsal, is the larger and wider (Pl. IV, fig. 27, J_1 and *J.*). These jaws bite vertically with great force, tearing up the food captured and held by the suckers before it is passed on to the rasping action of the radula. The anterior edge of each jaw is thick, and dark brown in colour. The trenchant border is sharp, and a raised ridge some distance behind this gives attachment to the muscles working the jaws (fig. 27, *r.*). This part of the jaw is exposed by cutting away the lip (Pl. IV, fig. 24). Further in, they decrease in thickness, and their colour lightens, and posteriorly they are thin, colourless, and semi-transparent. On the floor of the pharynx, slightly anterior to the middle point, is a muscular outgrowth—the tongue (fig. 24, *t.*). This forms the anterior wall of the Radula sac, at the base of which is the growing point of the radula (fig. 24, *rad.*). The Radula is a broad chitinous ribbon which, issuing out of its sac, runs over the upper and anterior surface of the tongue, which is responsible for the rasping action of the radula, as it works forwards, backwards and laterally. The tongue is strengthened internally by two small cartilaginous strips, which give it rigidity and also provide attachment for its motor muscles. Here, then, the food cut up by the jaws is further triturated. The teeth of the radula are large, and each row consists of three on each side of a central large tooth. The innermost of the three is the smallest, and the outermost has a broad basal attaching portion (Pl. IV, fig. 25, *Cc.*, 1, 2 and 3). The radula, when removed from its sac, is about 50 mm. long. In front of the tongue is another outgrowth, the Sub-Radular organ, on the tip of which opens the duct from the posterior salivary glands. Thus the secretion from these glands is poured on to the food before it is acted on by the radula (fig. 24, *s.r.o.*, $s_1g_1d_1$). This duct enters the buccal mass below the radular sac, after running above the sub-lingual gland which is on the ventral surface of the bulb (fig. 24, *s.l.g.*). The paired ducts from the anterior salivary glands open into the pharynx laterally and posteriorly (fig. 24, *s.g.d.*). Thus it will be seen that the massive muscular wall of the buccal bulb is formed chiefly by the muscles working the jaws and the radula. Anteriorly it is attached to the bases of the arms by a circular muscle band (Pl. III, fig. 14, and Pl. IV, fig. 20, *circ. m.*), and posteriorly by two ligaments (Pl. VII, fig. 53). Posteriorly the pharynx is continued into the oesophagus.

The Oesophagus is a narrow tube running down posteriorly to the stomach (fig. 17, *oes.*), dorsal to the hepatic gland (Pl. V, fig. 38*a*). Its posterior end marks the limit of the stomodaeum, the stomach, spiral caecum and intestine being hypoblastic in origin in all Cephalopods, while that part of the rectum posterior to the aperture of the ink duct represents the very small proctodaeum (Korschelt and Heider).

The internal surface of the oesophageal wall is thrown into numerous longitudinal ridges (Pl. IV, fig. 18, and Pl. V, fig. 33). Internally it is coated by a thin chitinous layer, ridged correspondingly, which is continued posteriorly as the chitinous lining of the stomach (fig. 33, *Cut. L.*). About half-way down, the oesophagus bears a large pouch-like non-glandular dilation or crop. This is also lined with chitin, and folded, and serves as a food reservoir when the stomach is full (fig. 18, *cr.*). At the base the oesophagus dilates, and its wall and chitinous lining become smooth. (To expose the anterior part of the oesophagus it will be necessary to remove the ventral wall of the cranial cartilage and the sub-oesophageal ganglia.)

Salivary Glands. Eledone has five salivary glands:

1. Anterior salivary glands, 1 pair, closely applied to the external surface of the buccal mass, posteriorly (fig. 17, *r.s.g.*).

2. Posterior salivary glands, 1 pair, situated at the side of the crop (fig. 17, $r.s_1\ g_1$, and fig. 38*a*, $s_1\ g_1$).

3. One sub-lingual and median salivary gland, situated in the ventral wall of the buccal mass (fig. 24, *s.l.g.*).

These glands are granular in appearance, soft and spongy in texture, and of a translucent whitish colour. The anterior pair is much smaller than the posterior, and is attached in the angle between the oesophagus and buccal mass (Pl. IV, fig. 20, *s.g.*). They are flattened oval glands, bilobed posteriorly, and are about 16 × 12 mm. in large specimens. The duct leads from a slightly elevated ridge on the internal surface, inwards to the pharynx, and is very short. Along with the duct, the artery and nerve of the gland enter by this ridge (Pl. IV, fig. 22).

The posterior glands are large and flattened, and the crop must be turned aside to expose them fully. They are attached to the visceral sac by a suspensory ligament. The duct leaves the anterior internal region where there is a slight depression. Here also enters the artery of the gland (Pl. IV, fig. 21, $s_1\ g_1\ d_1$). They measure about 32 mm. × 25 mm., and the duct after a short course joins its fellow to form an unpaired median " posterior salivary duct," which runs forward alongside the oesophagus to the buccal mass (fig. 17).

The sub-lingual gland is oval, and thickened posteriorly (Pl. IV, fig. 23, *s.l.g.*). In those Cephalopods whose development has been studied, it arises as an infolding of the ventral wall of the pharynx of the embryo, below and anterior to the sub-radular organ. This infolded region then gives rise to many tubular caeca, each of which opens independently by a minute opening into the buccal cavity. These tubules, connected together by indifferent tissue, thus form the compact sub-lingual gland. The three salivary glands all consist of glandular secretory tubules, embedded in a stroma of connective tissue (Pl. V, figs. 34 and 35, *Tu.*, *Str.*). These tubules are closely adpressed in the anterior glands, but much further apart in the posterior glands, and branch dichotomously here (figs. 35 and 34). The secretory cells of the three glands are all similar, and are columnar with a basal nucleus. The secretion forms in globules in the anterior portion of the cell, and then falls into the lumen of the tubule (Pl. V, fig. 36). The secretion of these glands is a kind of mucus only, and contains no ferment whatever (Frédéricq and Bourquelot). The venous blood, collecting in the sinuses occurring in the stroma of connective tissue which binds the secretory tubules together, passes out directly into the perivisceral venous sinus.

Stomach. This is a very muscular grinding organ, reminding one of the gizzard of a bird. Its ventral and dorsal walls are thickened anteriorly into grinding pads. These are thick and stout, and ridged internally. The posterior and lateral walls are, however, thinner. The oesophagus opens into the stomach at its right anterior angle, and the origin of the spiral caecum and intestine is quite near this point (figs. 17 and 18). In size the stomach is rather less than the crop, and like the oesophagus is lined by an easily detachable layer of chitin. This lining is specially thick where it covers the grinding pads (figs. 18 and 19, ch_1, *pad.*). Where it covers the posterior wall of the stomach, however, it is smooth and thin. At the exit of the spiral caecum and intestine the cuticle ends, thus leaving a circular orifice through which food passes onwards from the stomach (Pl. V, fig. 38, *or.*). The food is ground in the stomach, and also well mixed up with the digestive fluid which enters from the spiral caecum (Bourquelot), so that here digestion takes place.

Spiral Caecum.—A narrow passage leading out from the stomach, soon bifurcates, and so gives rise to the spiral caecum on the one hand and the intestine on the other (Pl. V, fig. 38, *Int. ap.*).

The spiral caecum is in reality a long narrow sac, e.g., caecum in *Loligo*, which in the Octopodidae and others becomes curled in a spiral of one and a half turns. It is thin walled, and the internal septa are seen faintly from outside (Pl. IV, fig. 28). The columella of the spiral is on the side opposite to the intestine (fig. 38). On cutting open the caecum along the columellar edge, and pinning it out, it will be seen that there is a series of delicate folded valves, running transversely to its length (fig. 38, *v.*, v_1). Cuvier described a spiral valve running down the caecum in Octopus, but in Eledone there is a series of short transverse valves instead, closely set. They are widest centrally, and taper at their two ends, which are attached to the columellar region of the wall. Along this columellar region also runs a longitudinal fold, at the side of which enters the common hepatic duct, some distance from the anterior end of the caecum (fig. 38, *h. ap.*). Probably this fold guides the digestive secretion into the stomach and also into the intestine. Like the intestine, the inner wall of the caecum is not covered by any chitinous lining. It acts as a reservoir simply for the hepato-pancreatic secretion, and no food of any kind was recognised therein.

The Intestine. Leaving the stomach, this long, thin-walled, and slender organ, after running between the two hepatic ducts, before their fusion, curves ventrally upwards over the liver, over the ventral surface of which it runs, curving first to the right, then in again to the left, and then anteriorly to the anus. Just before it reaches the anus, the ink duct enters the rectum by an aperture at the tip of a small papilla on its dorsal wall. The anus has a dorsal and a ventral lip, and bears two small leaf-shaped appendages or " ears " laterally (Pl. IV, fig. 29). The internal wall of the intestine is ridged, the two most prominent ridges being continued up from the columellar ridge of the spiral caecum. In the initial part of the intestine, the food which has been in great part digested in the stomach is mixed with that portion of the hepato-pancreatic fluid which enters this organ. Hence digestion is completed here. The chief process, however, occurring in the intestine is absorption of the now digested food. Towards the rectal end of the intestine, waste matter of a dull orange tinge collects.

Digestive Gland.—This large oval gland, although often called the liver, does not secrete a fluid at all comparable to the bile secreted by the liver of vertebrates. It occupies almost the whole of the visceral sac, and lies ventral to the crop and oesophagus. Although in Eledone it consists of one lobe only, the paired ducts and the analogy with the Decapods indicate a fusion of two originally distinct glands, which were situated laterally to the gut. The ink sac lies in a deep groove excavated on the ventral surface of the liver (fig. 17), and the two organs are surrounded by a common iridescent membranous envelope, outside and in addition to their individual coverings. In a freshly obtained Eledone a bilobed oval whitish region can be distinguished round the origin of the two hepatic ducts (Pl. VIII, fig. 32, *P.*). This is the so-called pancreas, and shows up distinctly against the yellowish green liver. The digestive gland as a whole is soft and spongy, and enclosed in a very delicate membranous envelope. It is built up of branching secretory tubules which open into the hepatic ducts. The pancreatic tubules likewise open into these ducts, further down.

According to Bourquelot, the digestive hepato-pancreatic fluid poured into the spiral caecum is colourless before digestion, and brownish after it. The hepatic secretion consists of diastase, trypsin and pepsin, while the pancreas secretes diastase also.

The opaque rather thick-walled hepatic ducts run posteriorly, and after embracing the intestine unite to a common channel which enters into the spiral caecum (fig. 28). Hence the order of events in the digestive economy of Eledone is as follows:—

(1) Food seized by the suckers is torn up by the jaws and passed into the mouth.

(2) Here it is mixed with the mucous secretion of the sub-lingual and posterior salivary glands.

(3) Next the radula rasps it and further breaks it up.

(4) As it passes into the oesophagus the secretion of the anterior salivary glands is poured over it.

(5) Now it passes to the stomach. Here the food is ground and mixed well. The hepato-pancreatic ferments enter from the caecum or reservoir, and become mixed with the food, and so digestion takes place.

(6) Next the food passes on out of the stomach into

the intestine, being prevented from entering into the spiral caecum by the folds of the wall in this region.

(7) In the intestine digestion is finished, as some proportion of the digestive fluid enters here. This region is, however, chiefly that of absorption. After this, the waste matter passes up to the anus and is ejected.

The Ink Sac, or anal gland of Eledone is a long, somewhat pear-shaped gland, which opens into the dorsal wall of the rectum, on a slight papilla, very near the anus (Pl. IV, fig. 30, *I. p.*). It is a much less developed structure than the ink sac of the Decapoda, and, unlike the latter, lies embedded in a groove on the ventral surface of the liver, in a median position (Pl. VIII, fig. 32). To expose it, the visceral envelope, and then the common iridescent membrane round the liver and ink sac, must be removed. Its dorsal wall lies in close contact with the ventral epithelial wall of the liver. When the enveloping membranes have been removed, the ink sac shows as a dull metallic dark-blue organ. Great care must be taken not to cut the wall, for the thick viscous secretion is exceedingly hard to get rid of, and stains the dissection deeply. The nerves should be traced before removing the visceral envelope. They come from two sources in Sepia, and probably also in Eledone (Girod). However, only those from one source have been followed out, i.e.:—

(1) The visceral nerves running over the liver, in the neighbourhood of the ink sac, send several branches inwards, which end in its walls (Pl. VIII, fig. 31, $I_1 S_1 N_1$). Near the posterior end of the sac, a specially large nerve runs in from each visceral trunk, and this, after pursuing a downward course until it meets the artery and vein of the ink sac, enters the gland along with them (fig. 31, *I.S.N.*).

(2) In Sepia a branch from the gastric ganglion may be followed up the wall of the intestine to its tip. At the point where the ink duct joins the intestine this nerve gives off a very fine branch which runs down the wall of the duct and gland to the posterior end. This nerve regulates the secretion of pigment, while the visceral nerve branches control the muscular contraction of the ink sac (Girod).

The ink sac has rather an elaborate vascular system. The abdominal aorta, running up from the heart to the intestine, gives off a vessel to the ink sac (Pl. VI, fig. 49, *I.S.A.*). This enters at its base, first giving off at each side a spirally curved vessel to the corresponding lobe of the pancreas (fig. 32, *P. A.*). Then it divides into four vessels, which become embedded in the wall of the ink sac and send branches to the internal glandular trabeculae. The ink duct also receives a small artery from the terminal portion of the intestinal vessel.

The vein runs from the sac into the posterior part of the anterior vena cava (posterior hepatic vein). It is formed by the union of two vessels which run one on either side of the ink sac and unite at its base. On their way these receive branches from the sac, and much longer ones from the liver and pancreas (fig. 32, *I.S.V.*).

Structure.—Cutting a sagittal section of the gland, the following portions may be seen:—(1) The basal glandular part (Pl. IV, fig. 26, *I. gld.*); (2) the reservoir above this (fig. 26, *Res.*); and (3) the duct, of about equal length with the gland. Its terminal portion lies external to the visceral envelope (fig. 32), and bears two internal valves, just near the anterior end.

The glandular part, after being well washed, will be seen to consist of numerous trabeculae, which branch and run into one another (fig. 26, *tr.*). These are membranous, perforated by small holes, and consist of a thin layer of connective tissue covered on either side by the secretory columnar epithelium. An oblique diaphragm limits the region of the gland, and is perforated by a hole for the passage of the ink. At the base of the gland is found a whitish mass of round non-glandular cells (fig. 26, gld_1). This is the formative region where the trabeculae originate. The initially indifferent cells become differentiated into either the connective tissue or the secretory cells of the trabeculae. These trabeculae are constantly being formed and travelling forwards to the anterior end of the glandular region. Tracing their course and structure as they go, it is found that the young cells gradually accumulate pigment granules, and when they are full burst. Thus the ink is freed and the secretory cells destroyed. Towards the anterior end of the gland, then, the trabeculae disintegrate, and are constantly replaced by the younger ones behind (Girod). The secretion is a thick dark-brown liquid, and a few drops will colour a large volume of water. On drying, a dark-brown powder is obtained. The liquid consists of a colourless transparent plasma, having minute dark-brown pigment granules in suspension. On analysis it is found to contain both copper and iron, extracted from the blood (Girod). Although the actual secretion of the ink is continuous, its passage to the exterior is intermittent and voluntary. After expulsion from the anus, the ink is discharged, along with a jet of water, through the funnel.

CIRCULATORY SYSTEM.

In order to dissect the vascular system of Eledone adequately, it is necessary to inject the vessels. The venous system is best injected from the anterior vena cava, and the arterial system from the base of the efferent blood vessel of one side. As the veins lie more superficially than do the arteries, it is best to follow them out first. If dissecting one specimen only for all the systems, only the main blood vessels, e.g., the anterior, abdominal, genital and efferent arteries, the three venae cavae, and the veins of the arms, can be followed satisfactorily.

The circulatory system will be described under the following headings: (1) Blood, (2) Heart, (3) Arterial system, (4) Venous system.

The course which the blood follows in the body may be briefly summarised as follows: Blood which has been aerated in the gills returns by means of the two efferent vessels to the auricles, and thence into the ventricle of the heart. From there it passes out to the body by the anterior, posterior and genital aortae, and ultimately reaches the arterial capillaries. Thence passing into the veins, it finally enters the lateral venae cavae, which take it back to the gill, thus completing the circulation.

Blood.

The blood of Eledone is a clear limpid fluid, of very pale blue colour. For examination it may be easily obtained by opening the efferent artery, at the base of the gill, or the anterior aorta, or again the anterior vena cava. In contact with the oxygen of the air the blue colour soon deepens. The various constituents of the blood are:—

(1) Small colourless amoeboid and very granular

corpuscles of 15 μ diameter (Pl. VI, fig. 44), with rounded or slightly curved nuclei. After a lapse of several minutes, these corpuscles are seen—if the blood is placed in a watch-glass after withdrawal from the body—to congregate together in large clusters.

(2) A liquid medium, in which the above corpuscles float, containing: (1) Mineral salts (including iron in small quantity, Girod); (2) slight traces of organic compounds; and (3) 9 per cent. of the substance Haemocyanin, an albuminous compound containing copper. According to Cuénot, it is the great quantity of copper present which gives the blue tinge to the blood. This darkens when exposed to air, because of the oxidation of the copper. The blood of Eledone, like that of all Cephalopods, contains no fibrin. The analysis of the contents of the blood plasma has not been made for *E. cirrosa*, but Frédéricq and Cuénot made it for Octopus and Sepia respectively. Two glands have been suggested as the seat of origin of the blood corpuscles: (1) The branchial gland (Joubin), and (2) the white body (Faussek).

HEART.

In Eledone the heart is situated just behind and to the right of the stomach (Pl. VI, fig. 42, *V.*). It is, however, rather ventral to this organ, but dorsal to, and therefore concealed by, the kidneys

The heart is rather smaller than the stomach, and consists of three chambers, two auricles and a central ventricle, into which the auricles open laterally, one at each side. The two auricles are essentially the dilated and slightly muscular basal portions of the efferent branchial vessels, and may be defined as the portion of these vessels lying between the posterior end of the gill and the ventricle (fig. 42, *au.*). The auricles are symmetrical, but the thicker walled, more fleshy ventricle is asymmetrical in shape. The walls of this chamber are muscular and, unlike the dark coloured branchial hearts, of a whitish colour. The inner surface is produced into numerous branching and interlacing fleshy pillars, which are bathed in arterial blood (Pl. VI, fig. 45). The cavity of the ventricle is incompletely divided into two chambers by a fleshy partition which probably aids in ensuring the distribution of blood through all three aortae during the period of systole. This is triangular in shape, and as the dorsal and anterior edges are attached to the corresponding walls of the heart; while the basal side hangs free, an incomplete vertical septum is thus formed. (Pl. VI, figs. 47 *a* and *b*, *tr. s.*, and fig. 45). The right auricle leads into the right chamber, and the left auricle similarly into the left chamber of the ventricle. The anterior aorta is given off from the right anterior dorsal corner of the heart, while the abdominal aorta leads out of the ventral surface of the left chamber and the genital aorta from the posterior dorsal wall of the same (figs. 45, 46 and 47). Two semi-lunar valves guard the entrance of each auricle into the ventricle. The free edge of each is directed inwards into the ventricle (fig. 48, *au. v.* and au_1 v_1). Consequently, at the moment of diastole they open and allow blood to enter the ventricle from the auricles, and at this time the blood in the two chambers of the ventricle can mix freely. However, at the moment of systole the valves close and prevent the reflux of blood into the auricles. The ventricle is now completely divided into two chambers by the partition, and the blood from the right chamber is forced up the anterior aorta, while the blood in the left flows into the abdominal and genital aortae. The anterior aorta also has two smaller semi-lunar valves at its base. These have their free edges turned towards the aorta. They close during diastole, and open during systole.

Arterial System.

The arterial blood in Eledone, as in Octopus, is wholly enclosed in definite vessels. These have muscular walls, which are consequently stronger and thicker than the membranous walls of the veins. The pressure of the blood in the arteries is very great indeed, but is slight in the veins (Frédéricq). As mentioned previously, the arteries of Eledone radiate from three main trunks:—(1) Anterior aorta, carrying blood to the cephalopedal mass, the mantle and anterior portion of the alimentary canal; (2) abdominal aorta, carrying blood to the intestine and ink sac; and (3) genital artery, running direct to the genital gland.

The anterior aorta is a large vessel which, leaving the heart, runs forwards, and curving round the liver runs dorsal to this organ, and then lying to the right of the stomach follows its outline for a time. Then, entering the large venous sinus surrounding the oesophagus, it runs alongside and to the right of the latter almost as far as the cranial cartilage (fig. 42, *Ant. A.*). Soon after its origin, the anterior aorta gives off a large branch which immediately bifurcates into the right and left pallial arteries (fig. 42, *L. Pall. A.*). The right vessel curves round dorsal to the aorta, and then runs internal to the visceral envelope, towards the funnel retractor. Just interior to this it gives off a vessel which runs up anteriorly, on the inner side of the visceral envelope, giving off several small branches during its course (fig. 42, $V_1E_1A_1$). This artery, after furnishing several small branches to the retractor infundibuli, ends in the base of the funnel. The main pallial vessel now runs below the posterior part of this funnel retractor muscle, and so gains the inner face of the ventral part of the mantle, and then runs obliquely to the stellate ganglion (fig. 42, *St. G.*). On its way it gives off several branches to the right and left, which end in the substance of the mantle. Running below the stellate ganglion, the pallial artery ends in several branches which divide up in the mantle substance.

The left pallial artery runs just internal to the visceral envelope, dorsal to the stomach, where it gives off a posterior branch to the visceral envelope. Then, running almost transversely to the left, it gains the left depressor of the funnel, after giving off an anterior branch. From this point its course is similar to that of the right pallial artery (fig. 42, *L. Pall. A.*). Entering the venous sinus, the aorta gives off a second large branch, the visceral artery, which immediately gives off a branch ending in small arteries on the right side of the stomach. Next it gives off a large hepatic artery, which enters the liver dorsally and posteriorly, and breaks up in its substance (fig. 42, *Hep. A.*). Then, running down the groove between the oesophagus and the stomach, it gives an anterior branching artery to the lower part of the oesophagus (fig. 42), an artery to the left wall of the stomach, a branch to the intestine, and ends in many branches to the spiral caecum. The aorta is hidden anteriorly by the crop and salivary glands; when these are turned aside it may be seen to give off a branch at the level of the crop to the alimentary canal (fig. 42, *Oes. A.*), and this branch gives off an anterior and a posterior fork to the corresponding parts of the oesophagus, and several branches to the walls of the crop. Near the anterior end of the visceral envelope, the aorta gives off a small dorsal artery to the muscles of the neck (fig. 42, *N.A.*), and then divides into two smaller forks which run one on each side of the oesophagus. An aperture on the ventral surface of the brain, between the anterior infundibular nerves, allows these two arteries to leave the central cavity of the brain, through which they pass posteriorly, and gain the ventral surface of the buccal mass, over which they run obliquely (fig. 42, *C. A.*). At the anterior end of this mass, each cephalic artery divides again. A second division of these four branches now gives the eight brachial arteries (fig. 42, *Arm. A.*) which supply the arms.

Each brachial artery runs down the centre of the arm, external and closely applied to the brachial nerve (Pl. VIII, fig. 80). Externally it gives off a series of small arteries all along the arm, to the muscles and skin of the external surface of the arm, and to the web (Pl. VIII, fig. 79). Internally the brachial artery furnishes two branches to each sucker (fig. 79, *S. a.*). These run up one on each side of the corresponding nerve ganglion, and penetrating the muscles of the arm, end in superficial small branches on the sucker and internal surface of the arm. The brachial artery extends to the tip of the arm, its size decreasing with the corresponding lessening of that organ towards the tip.

Although the anterior and posterior salivary glands are widely separated from one another, yet their arteries have a common origin. Soon after its bifurcation, the anterior aorta gives off two branches, one from each fork (fig. 42). Each branch immediately divides again, one artery running posteriorly to the corresponding posterior salivary gland, which it enters anteriorly (fig. 42, S_1 A_1), and one branch (the pharyngeal artery, fig. 42, *Ph. A.*) running anteriorly to the buccal mass.

The pharyngeal arteries run forwards, one on each side of the oesophagus, through the cranial cavity, and emerging with the oesophagus reach the buccal mass. Here each artery runs below the sub-oesophageal ganglion, but internal to the neurilemma of this ganglion, i.e., between the neurilemma and the ganglionic substance, and then divides into three branches. One of these supplies the anterior salivary gland (Pl. VI, fig. 50, *S. A.*), the anterior branch supplies the anterior lateral wall of the buccal mass, and a third branch runs ventrally, to supply the ventral posterior portion of the buccal mass (fig. 50, $B_1 A_1$, *B. A.*). Small arteries accompany several of the nerves given off by the suboesophageal ganglion. Anterior to the salivary and pharyngeal arteries a second branch is given off which divides into several arteries: (1) an artery giving off a branch to the funnel (fig. 42, *F. A.*), and then running down on the inner side of the visceral envelope, to end there by splitting up into many smaller branches (fig. 42, *V. E. A.*); (2) a branch which follows the course of the accessory pallial nerve, and so supplies the muscles of the head, and the lateral chamber of the funnel; (3) a branch to the eye (fig. 42, *O. A.*); and (4) a short branch running inwards to the statocyst. The next branch given off by these forks is a second artery to the eye (fig. 42, *O. A.*). A second very fine branch to the anterior part of the funnel is the last branch given off by the two forks of this aorta (fig. 42, $F_1 A_1$).

The Abdominal Aorta is much more slender and less important than the anterior aorta. It arises anteriorly from the ventral wall of the left chamber of the heart, and runs forwards and ventrally. Soon after its origin it gives off a left and right branchial artery. Each of these runs transversely across to the corresponding gill, just dorsal to the kidney sac, and ventral to the auricles (fig. 42, *Bl. A.*). Further along, the abdominal aorta gives off the artery of the ink sac, which runs inwards and forwards to the base of that organ, giving off two branches to the intestine on its way (Pl. VI, fig. 49, *I. S. A.*, *Int. A.*). The abdominal aorta now curves ventrally, and can be seen on the ventral surface of the visceral mass, between the two diverging anterior ends of the kidneys (Pl. V, fig. 37, *Abd. A.*). After giving off a fairly large branch to the septal muscle (fig. 42, *Sept. A.*), the abdominal aorta runs up alongside the intestine, to end in fine branches on the rectum. In its course it gives off several small intestinal branches, and also a second septal branch (fig. 42, $Sept_1$ A_1). To the left of this is an important branch which terminates on the rectum, after giving off several ramifying branches to the surface of the liver, and a branch to the duct of the ink gland.

The right branchial artery, soon after its origin, gives off a coronary artery to the walls of the ventricle. The left branchial artery, running behind the left kidney sac, soon bifurcates (Pl. VI, fig. 51, *L. Bl. A.*). One of the two forks running along to the oviduct, gives off one or two small branches to the auricle, and at the level of the oviducal gland sends off a recurrent branch which runs down between the water canal and the oviduct, to end in fine branches on the wall of the genital capsule (fig. 51, F_1, *Rec.*). Other branches given off by this fork run to the flask-like portion of the coelom, to the anterior part of the oviduct (fig. 51, *od.*), and to the oviducal gland. The other fork (fig. 51, F_2), after giving off a branch to the genital capsule, runs over and feeds the branchial heart, sends a second branch to the gonad, and ends in a vessel running to the gill tip—alongside the branchial nerve and supplying each leaflet with nutrient vessels (fig. 51, *Bl. A.*).

The Genital aorta is an independent artery, given off by the postero-dorsal wall of the left chamber of the ventricle. It runs posteriorly to the genital gland, and ends in several ramifying branches to this organ (fig. 42, *G.A.*).

VENOUS SYSTEM.

The blood which has been carried to all parts of the body by the arteries, ultimately passes from the arterial to the venous capillaries, and then flows into a system of veins with definite walls, which carry the de-oxygenated blood back to the gills for aeration. Hence in Eledone, as in most Cephalopods, the circulatory system is highly organised. But still there is one large venous sinus through which blood flows on its return to the gills.

The blood from the arms is collected into two rather wide, superficial vessels, which run one on each side of the arm (Pl. VII, fig. 54, *Arm* V_1, *Arm* V_2, and fig. 52). These lateral veins, externally or aborally receive branches from the aboral part of the arm, and from the web. Orally they receive a series of vessels which alternate with the suckers (Pl. VII, fig. 58). All these veins are superficial. The alternating vessels of one side of the arm anastomose at their origin with those of the other side of that arm (fig. 58). Towards the bases of the arms, these brachial veins join in pairs (figs. 52 and 54), each pair being formed by the neighbouring veins of any two successive arms. Thus eight vessels are formed, which run in the grooves between the arms down to the level of the anterior border of the head (fig. 52, *Br. V.*). On the way they receive numerous branches from the surface of the arms and the web. The posterior ends of these eight vessels are united by a circular vessel of similar width, which embraces the head superficially, just anterior to the eyes. Ventrally this cephalic vessel joins the anterior vena cava, a wide vessel running over the ventral wall of the cranial cartilage and the liver, down to the kidneys. At the anterior end of these it bifurcates, and each half runs behind the corresponding kidney and soon meets a vessel running in from the middle region of the venous sinus (fig. 52, *Abd. V.*). These two vessels join to form the Lateral Vena Cava of that side, which slants outwards and downwards to the branchial heart, behind the kidney (fig. 52, *L. V. C.*). From the antero-external angle of this heart the blood is led by the afferent branchial vessel to the gill, and is distributed to branches which feed each filament, and becoming aerated as it passes through the thin gill laminae, is collected again into the efferent vessel of the gill. The circular cephalic vessel also receives the venous blood from the superficial muscles of the head and neck by means of small branches which run into its aboral wall (fig. 52, *Ceph. V.* and *Sup. V.*). The ventralmost of the eight interbrachial vessels appears to run into the cephalic vein sometimes to the right and sometimes to the left of the origin of the anterior vena cava. Some superficial muscles must be dissected away to expose the circular vessel fully.

Below the origin of the second ventral interbrachial vessel on each side, a large vessel runs in from the surface of the mantle and the eye (fig. 52, *M.V.*). The origin of this vessel is in the mantle. The whole of the anterior part of the mantle is drained (Pl. VII, fig. 57) by a series of vessels of which only (1) is on the internal surface, while (2, 3 and 4) are external. These four vessels unite to form one, which then receives a branch from the postero-dorsal surface of the eyeball, and one from the corresponding lateral wall of the funnel (fig. 52, $F_1 V_1$). Running up the ventral surface of the eyeball, just below the skin, this vessel, after receiving small branches on its way, joins the cephalic vessel. The posterior part of the mantle is drained by veins which radiate from a vessel running through the substance of the mantle from its internal surface (figs. 52 and 57, M_1V_1). Here it is joined by the pallial vein, and a vein from the so-called branchial "blood-making gland." The large vessel formed by the union of these three enters the lateral vena cava ventrally just before the latter enters the branchial heart.

The pallial vein runs ventral to the corresponding pallial artery, down from the stellate ganglion towards the branchial heart. It is formed by the union of an anastomosing network of vessels over the ventral surface of the stellate ganglion, a branch from the great lateral muscle, and several branches from the mantle, and on its course receives several small pallial veins (fig. 52, *Pall. V.*).

The Anterior Vena Cava lies on the median ventral surface of the visceral mass and is exposed at the same time as the visceral nerves, by removing the septal muscle and the epithelium covering the visceral mass. It lies to the left of the rectum. Its walls are membranous and semi-transparent. Posteriorly, as mentioned, it ends in two forks which help to form the lateral venae cavae, and anteriorly it originates in a vessel given off from the ventro-posterior wall of the anterior division of the great venous sinus (figs. 52 and 53, S_1V_1). Soon after its origin it bifurcates, and the two halves run round the origin of the internal funnel protractors, and join again below it (fig. 52). Each of these halves receives a vessel which comes from the venous sinus surrounding the white body, optic ganglion, &c., of the eye, pierces the ventral cranial wall obliquely, and then enters the vena cava (fig.

52, *Orb.V.*). Just behind the origin of the funnel protractors are seen two veins from the muscles of the head, and a single ventral vein formed by the union of two running down the back of the funnel (fig. 52, *F.V.*). At the level of the posterior edge of the funnel another branch enters, which is formed by the union of branches from the anterior surface of the visceral envelope and the posterior dorsal funnel wall (fig. 52). Further back the anterior vena cava receives a vessel dorsally from the antero-ventral surface of the liver. This vessel also receives a vein from the wall of the rectum. Ventrally, about the same level, a pair of veins comes in from the funnel depressors, receiving small branches from the visceral envelope on their way. The next branch is from the septal muscle, and is succeeded by another large vein from the liver, entering dorsally, and draining the posterior part of this organ. The final vessel which enters, just before bifurcation, is from the intestine. The small side fig. in fig. 52 illustrates the two valves at the anterior end of the vena cava.

The Lateral Venae Cavae, and the two vessels which run into them from the venous sinus, bear the so-called venous appendages on their posterior walls (fig. 52, *Abd.V.* and *L.V.C.*). These appendages are club-shaped outgrowths of the vessel wall, arranged in five or six irregular rows, the narrow end being that by which they open into the veins. On opening up the lateral vena cava (fig. 56) and examining the posterior internal wall, one sees the circular aperture leading into each venous appendage. This aperture opens into a short vessel whose walls are again pierced by other smaller apertures leading into a smaller series of vessels similarly pierced, and so on, so that each appendage contains in its interior a system of radiating vessels which ultimately opens into the great vena cava; and the blood in the vena cava thus penetrates into this intricate system in the appendages on its way to the gill. Now externally these appendages are covered by the glandular wall of the kidney, as they encroach on the cavity of the kidney sac. They show many furrows and minute holes on their external surface, which are lined by the glandular kidney epithelium. Hence the blood contained in the vascular network in the appendages comes into intimate connection with the glandular cells of the kidney, and is deprived of its excretory products. The appendages are spongy and yellowish in colour, and show through the ventral transparent wall of the fresh kidney. The two vessels running to the venae cavae from the venous sinus each give off a small branch to the ventricle near their ventral ends (fig. 53, *Cor.V.*). Into the right abdominal vein opens a large vein formed by the union of many branches from the genital gland. Half way along its course this vein receives two lesser vessels from the dorsal region of the visceral envelope, and a branch from the spiral section of the sinus (fig. 53, *V.E.V.*).

The Branchial hearts are purplish glandular organs at the base of each gill, into which the lateral venae cavae open, one at each side (Pl. VII, figs. 52 and 55). This round opening is guarded by two semi-lunar valves which open into the afferent vessel, and prevent the reflux of blood from the gill (Pl. VII, fig. 56). The branchial heart is an organ with very thick spongy walls, composed of soft cellular tissue. The central lumen, however, which these walls enclose is very small. On the internal surface of the wall numerous large and small holes may be seen, which lead into short canals (Pl. VII, fig. 56), from which other smaller passages lead off, and a third series from the second, and so on, the ultimate apertures leading into small caeca. Hence the wall of the branchial heart is penetrated in every direction by a system of short vessels, which lead ultimately into the lumen of the heart. Therefore venous blood, on entering the organ, penetrates into this system of vessels before it passes on into the afferent vessel which is given off at the antero-external angle of the heart. Cuénot considers that the purplish colour of the branchial heart is due to the purplish concretions found in the cells of which it is composed. By experiment he has proved that these cells are excretory, and therefore that the branchial heart is a glandular organ. The venae cavae, branchial hearts and vessels, and main aortae, as well as the heart, are all rhythmically contractile.

The Venous Sinus extends from behind the mouth to the posterior edge of the stomach, and is divided into three cavities anterior, central and posterior, the first two of which communicate by important vessels with the large veins. The wall of the sinus is a tough transparent membrane.

1. The anterior division is small and is joined to the middle division by a narrow region, which runs with the oesophagus through the cavity of the ring-like central nervous system (fig. 53). The thin wall becomes adherent to the buccal mass about half-way down its length (fig. 53, *B.M.*), thus forming the anterior boundary of the sinus. Hence the posterior portion of the buccal mass, the anterior salivary glands, and the anterior portion of the oesophagus, are bathed in the blood contained in this division of the venous sinus.

2. The central division is much larger, and narrower in the middle region than at its two extremities, and contains the oesophagus, crop, posterior salivary glands and stomach. However, the liver and ink sac,

enclosed in their common envelope, lie wholly outside and ventral to the sinus (fig. 53, S_2V_2). The anterior aorta penetrates into the latter at the anterior end of the stomach, and runs therein, leaving it only after its anterior bifurcation. Several small infoldings of skin attach the stomach to the wall of the sinus, forming small mesenteries (fig. 53, *Mes.*). The two abdominal veins running from this cavity to the venae cavae, leave it dorsally, one at each side, towards the anterior end of the stomach (fig. 53, *Abd.V.*). Thus the blood from the sinus is drained off by these, and passes direct to the lateral venae cavae, and thence to the gills.

3. The posterior division contains the spiral caecum, which is attached to its wall by several small mesenteries. The anterior wall of this region is common to it and the middle division, but forms only an incomplete septum, allowing free passage of blood, as it is pierced dorsally and ventrally by a row of rather large holes (fig. 53, *Lac.*). The intestine soon after its origin pierces the wall of the middle region, and then bending up over the ventral surface of the liver, lies wholly outside the sinus (fig. 53). The two hepatic ducts pierce the wall of the posterior region, and uniting inside this part of the sinus, enter the spiral caecum. Into the adjacent portions of the venous sinus open small veins from the buccal region, lips, surface of the brain, and the different organs of the alimentary canal which float freely in the sinus.

RESPIRATORY SYSTEM.

(I) Respiration.

The respiration of Eledone appears to agitate the whole of the trunk. Water enters the mantle cavity by the anterior opening during the period of inspiration, when the sides of the body may be seen to swell outwards. At this time the anterior edge of the funnel curves inwards, and so causes the funnel aperture to become almost completely closed (Pl. II, fig. 7*a*, *f. cl.*). In this sketch it will also be seen that the anterior mantle slit is now widely opened, to allow the water to pass inward (*m.op.*). Inspiration is accompanied by a slight movement upwards and backwards of the whole body. During expiration, the walls of the body contract again, as the amount of water contained in the mantle cavity becomes greatly diminished. This water is, however, bound to go out by the anterior funnel aperture (fig. 7*b*, *f.op.*), for this is now wide open while the mantle slit is tightly closed by the locking apparatus (fig. 7*b*, *m.cl.*). With expiration the body moves slightly downwards and forwards. When a stream of borax carmine was passed in at the mantle aperture, during inspiration, it was passed out again as a red jet, from the anterior funnel opening, during expiration. Thus the way the respiratory water passes was indicated. The stream of water thus ejected is sent out with great force, and disturbs the surrounding water for a considerable distance. There appears to be no constant rate of respiration. After a period of rest, say in the early morning in an aquarium, the rate is sometimes as low as six per minute, while after agitation it increases to sixteen per minute. During the daytime it averaged twelve to fourteen. Smaller specimens appear to breathe rather more rapidly than larger ones. While resting, the tip of the funnel is generally seen protruding either from below the right or the left side of the body (Text fig. I). Every now and then Eledone changes the funnel over from one side to the other, and while so doing the respiratory movements slacken considerably. Often the body will be noticed to heave convulsively, and the respiration to quicken greatly, for a short time, when there is no apparent cause for disturbance.

(II) Respiratory Mechanism.

1. **Gills.**—Eledone, in common with all the living Cephalopods except *Nautilus*, is Dibranchiate, i.e., it has a single pair of gills. Morphologically these gills represent part of the inner surface of the mantle, which has been specialised for respiratory purposes. They are situated in the mantle cavity, laterally to the visceral mass. When the mantle is cut open, and turned back (as in fig. 11), they may be seen slanting obliquely outwards and upwards from the posterior end of the visceral mass. In fig. 8, which shows the left division of the mantle cavity, only one may be seen. They are attached both to the mantle and to the visceral mass. The gill may be considered as a slender hollow cone, with the apex pointing upwards and outwards. The hollow which forms the base leads into the cavity of the cone, whose walls are formed by the branchial leaflets. The cone is, however, laterally compressed, and is attached to the mantle dorsally, but free ventrally. Along this dorsal attached axis of the gill runs the afferent vessel, while along the free one runs the efferent vessel, so that the plane joining these two axes bisects the gill, and is at right angles to the plane of the mantle. The tip of the cone is situated just posterior to the level of the anus, while the base is slightly behind the urinary papilla. Below this may be seen the branchial heart, which, receiving blood from the body, pumps it on through the afferent vessel to the gill for aeration. Posteriorly the gill is bound to the visceral mass by—(1) The two muscular bands, mentioned in the description of the mantle cavity. The first runs down the ventral side of the efferent vessel, from its tip, and then,

leaving this vessel at the base of the gill, is continued in towards its fellow over the ventral side of the visceral mass. The second, running along the inner side of the afferent vessel from its tip, is inserted with the depressor infundibuli into the mantle, at the anterior end of the mantle cartilage of its side. These two bands of muscle probably serve to deflect the gill, and also by their contraction help the circulation of blood in the vessel each respectively covers. (2) The afferent and efferent vessels, which are continued from the gill into the visceral mass, help to bind them.

The septum which joins the mantle and gill together is triangular in shape. The apex of the triangle points posteriorly, and the base, which is the shortest side, anteriorly. This side is free, and allows the gill to be deflected laterally. That side of the triangle which joins on to the mantle is the longest (Pl. V, fig. 59, *Br. mem.*). The dorsal part of the septum is thin, membranous and transparent in a fresh specimen, but along the edge attached to the gill runs a broad fleshy band, the so-called "spleen," which lies dorsal to the afferent vessel (fig. 59, *Br.gld.*). During life the gills are exceedingly graceful objects, semi-transparent and colourless, and are deflected laterally to and fro in the mantle cavity.

The structure of the gill is exceedingly complex, much more so than the gill of Sepia and other Decapods. The walls of the hollow gill cone are formed by pillars of connective tissue penetrated by blood vessels, and bearing the aerating filaments on their outer surface (Pl. V, fig. 60). There are eleven to thirteen pairs of leaflets in Eledone, the number varying slightly with the size of the specimen. These are arranged in alternate pairs, i.e. the supporting pillars on the external side of the gill alternate with those on the internal surface. Counting towards the tip, from the base of the gill, the leaflets at first increase in size, the third pair being the largest, and from here they gradually decrease towards the tip. The aerating filaments stretch from the afferent to the efferent vessels, and each leaflet is separated from its neighbours by a slit. Hence water can pass in and out of the cavity of the gill either by the hole at the base, or by the slits between the gill leaflets. Looking through these slits on the external side of the gill, the leaflet of the other side may be seen (fig. 60, *L.* and L_1). This sketch shows a part of the gill from the internal side. At the bottom is the branchial gland, and from it three gill leaflets may be seen running ventrally to the efferent axis of the gill. The centre leaflet has been taken away except for a part at the base, in order to show more clearly the two alternating ones on the opposite side. Posteriorly, these leaflets are attached to the outer side of the afferent vessel which runs up the gill on the inner side of the spleen (Pl. VIII, fig. 63), lessening in size as the gill narrows to the tip. Thus the afferent vessel, covered over by the general lining of the mantle cavity, forms the dorsal wall of the cavity of the gill. Similarly on the outer edge of the gill, the efferent vessel runs from its tip downwards, but a thin sheet of connective tissue (fig. 60, *C.T.*), running inwards into the gill cavity from the efferent axis, along the median plane, separates the efferent vessel from the cavity of the gill, and forms the ventral boundary of the latter (figs. 60 and 63).

The complex gill-leaflets are attached ventrally to this sheet of tissue. First considering each leaflet as a single sheet, it is seen that the aerating portion or filament is on the external side of the attaching pillar, and is consequently bathed in the water of the mantle cavity. Hence blood brought into these filaments for aeration comes into contact with the constantly changing water supply of the mantle cavity, and is only separated therefrom by the very delicate tissue of the gill filaments. Now, each filament is not a plain sheet, but is crinkled or folded in such a way as to form half cylinders, which alternate with one another as do the leaflets themselves, on each side of the tissue which forms the axis of the filament. This may be understood from the figure where the crinkled filament is shown from the external surface (fig. 62, f_1, f_2, f_3). This sheet of alternating semicylindrical folds does not extend along the full length of the supporting pillar, but only along the anterior two-thirds in the case of all the filaments on the internal side of the gill, while those on the external side bear the aerating folds all along their length, and consequently there are more of these folds here (fig. 60, L_1). The number of aerating folds also varies, of course, with the size of the leaflet.

Now, if we consider each filament as an element of the first order, each of these is crinkled into alternating elements of the second order, these again, in the same way, into elements of the third order, and so on until the eighth series of elements is reached, these ultimate folds being microscopic. Accessory gill leaflets are situated on the vertical septum interior to the efferent vessel, and occur in pairs between successive leaflets (fig. 60, *L.acc.*) all along the gill. Probably they originally were attached to these leaflets, and now have moved slightly away. They equal one of the folds of the true leaflets in size. In shape they are triangular, the apex of the leaflet pointing downwards. Each is crinkled into five or six pairs of secondary elements, whose further structure exactly resembles that of the ordinary secondary element of the gill.

The afferent vessel of the gill runs along the dorsal wall of the branchial cone (Pl. VIII, fig. 63), ventral to the spleen, giving off alternate branches on its way, to the alternating internal and external gill leaflets. Narrowing down with the gill, it runs to its tip. The branch to the leaflet runs in the supporting pillar, and, therefore, on the side next to the gill cavity. Running along to the ventral side of this cavity, it joins another venous vessel, parallel to the main afferent vessel, and forming the ventral wall of the gill cone (fig. 63). Again, each of these vessels to the leaflets or primary elements of the gill, gives off similarly alternating vessels to the secondary elements of the gill (fig. 63, V_1, V_{11}), and so on. However, these vessels run along the outer edge of the secondary, tertiary, &c., elements (fig. 62). On the internal surface of the gill, where the leaflets do not bear secondary elements all along their axis, the four lowest folds receive blood from a common vessel (fig. 63). The secondary vessels running up along the outer edge of the corresponding folds, decrease in size and end on the external surface of the gill, at the tip of the fold (fig. 62). As there are eight series of gill elements, and consequently eight series of vessels, the ultimate ones are extremely fine. They open into a venous lacuna in the gill filaments, and the blood which by now is in great part aerated and arterial, is gathered up again into a network of arterial capillaries. Each accessory leaflet receives blood from a vessel given off by the vein parallel to the main afferent vessel, and described above. This vessel runs along the outer surface of the accessory leaflet and divides up exactly as do the branches to the secondary elements of the gill (fig. 63).

The finest arterial capillaries of the efferent vessels are situated in the eighth elements of the gill. Each fold here sends off rather larger vessels, that form a somewhat coarser meshwork in the seventh element, and so on, till the secondary elements are reached. Now, in the axis of each gill filament, about halfway between the internal and external surfaces, runs the artery from this leaflet, out to the efferent gill vessel (fig. 61, A_1). It originates in branches from the network of vessels in the secondary elements of the gill, and the latter must be turned aside to disclose both the artery and the network (fig. 61, *N.*).

The efferent vessels of the accessory leaflets also originate in a network of capillaries. The meshwork of arteries increases in size in succeeding elements of the gill. Ultimately they open into two vessels:—(*a*) A sinuous vessel common to, and between the two leaflets, and opening into the efferent vessel of the true leaflet between them, but on the opposite side of the gill (fig. 63, and (*b*) A sinuous vessel on the other side of each accessory leaflet, running into the efferent vessel of the leaflet adjacent (fig. 63, 2).

The so-called Spleen or branchial gland of the Cephalopods, would appear to have some intimate connection with the blood, as it is irrigated by both arterial and venous blood, and is placed close to the gill. It is built up of polygonal cells, separated by lacunae of various sizes containing blood (Pl. VI, fig. 63*a*; *b.s.* and *l.b.s.*). There are no true capillary vessels whatsoever. It receives blood: (1) from branches which, coming from the afferent vessel, furnish venous blood (fig. 63, *Aff.v*); and (2) from arteries running down the supporting pillars of the branchial leaflets. These arteries originate in a network formed by the arteries of the accessory gills (fig. 63). This blood mixes in the intercellular lacunae of the branchial gland,

and passing off in the vessel on its inner side, is carried back by a vein to the lateral vena cava (fig. 63, *Br. gld. V.*). This it enters just external to the branchial heart. Probably this gland is connected with the manufacture of the corpuscles of the blood of Eledone and other Cephalopods.

2. **Skin.**—As the skin of Eledone is very plentifully supplied with capillaries, especially from the venous system (figs. 57 and 58), it is possible that there is also a certain amount of cutaneous respiration.

COELOM.

All Molluscs have a reduced coelom, and a correspondingly dilated haemocoel. Although this phenomenon of "phleboedesis" has not been carried so far as in the Arthropoda, still (1) the coelom has ceased to be a true perivisceral cavity and its main remnants are the pericardium and the genital cavity, which still communicate with one another; and (2) large venous sinuses occur, forming a secondary body cavity.

Whereas in *Sepia* the pericardium and genital cavity are both well developed, and are only separated from one another by an incomplete dorsal septum, in *Eledone* and other Octopoda the pericardial division is greatly modified and reduced. It is represented by a pair of thin-walled, semi-transparent, flask-shaped pouches (Pl. V, fig. 40, *Coel.*), situated laterally, dorsal and posterior to the base of the ureters. Posteriorly each pouch contains the corresponding branchial-heart-appendage, or pericardial gland (fig. 40, *Br. app.*), while anteriorly it opens into the corresponding ureter, by an oval renopericardial aperture in the dorsal wall (fig. 40, *R. Pc. ap.*). The genital division of the coelom is well developed in

Eledone, and communicates with the exterior directly by means of the genital ducts and indirectly by means of the so-called "Water Vascular Canals." These are two long slender ducts leading from the genital gland into the pericardium. The right duct is partly shown (fig. 40, *W. V. C.*) where the canal runs dorsal to the right kidney and pericardium, and opens into the latter dorsally, just behind the reno-pericardial opening. In the female there are two symmetrical canals which are long, slender and thick-walled, and open posteriorly into the genital capsule (Pl. V, fig. 39, *W. V. C.* and *ap. int.*) These internal apertures are just exterior to the internal apertures of the oviduct (fig. 39, *l. od. ap. int.*). In the male, however, the right canal alone resembles that of the female in width and position, while the left is much wider particularly in the region near the genital gland— and opens into the genital capsule quite anteriorly (Text fig. VII, *A*.*p*. 90). In both sexes the pericardial pouches and the water canals are lined by ciliated epithelium, and as shown (Pl. VI, fig. 51), the water canal follows the course of the sexual duct for the greater part of its length.

EXCRETORY SYSTEM.

The Kidneys—a single pair of large transparent sacs are exposed by stripping off the epithelium which covers the visceral mass. They lie on the postero-ventral surface of the visceral mass, ventral to the heart and posterior to the greater part of the alimentary canal (Pl. V, fig. 37, *R.K.*). The left kidney stretches a little further forward than the right. In young females these sacs may cover the whole postero-ventral surface of the body, but in older females and all males the genital gland pushes them anteriorly and laterally, by its ventral protrusion (fig. 37, *G.*). Hence the kidneys tend to diverge posteriorly. They are triangular in shape, the longest side being external. As they are wholly independent of one another, they differ from the kidneys of *Sepia*, where the two are in direct communication. The ureter is situated half way down the external side of the sac, and bears the urinary aperture at the tip (fig. 37, *Ur. p.*). When fresh, the intestine, heart, liver, etc., may be seen through the transparent walls of the urinary sacs. On opening the kidney it is found to contain a thick colourless liquid in which may be seen yellowish accretions of guanin—both the liquid and the guanin being excretory products eliminated from the blood by the glandular cells of the kidney. Roundish colourless corpuscles are found floating in the kidney fluid, and also numbers of the small Mesozoan parasite, *Dicyema mülleri*, in various stages of development (Pl. X, fig. 81). Behind the kidney run the lateral venae cavae, and the two abdominal veins, and where these vessels touch the kidney wall they are produced into the club-shaped venous appendages. The kidney wall, which elsewhere is quite smooth, membranous and non-glandular, is composed of columnar glandular cells where it covers these appendages. As shown (Pl. VII, fig. 56), these "spongy bodies" have their surfaces furrowed by numerous folds and grooves, lined also by the glandular excretory epithelium of the kidney. The visceral mass dorsal to the kidney also protrudes into, and so encroaches on, the cavity of the sac. The ureters are canals about 12 mm. long, and are furrowed longitudinally on their inner surface.

The Pericardial gland is a white gland of somewhat depressed oval form, situated on the inner anterior wall of the branchial heart, and enclosed in the pericardium (fig. 40, *Br. app.*). Numerous folds run inwards from the free surface of the gland, and in cross section appear as narrow passages. From these passages secondary canals run into the substance of the gland, and end in rounded chambers. Into these chambers open minute caeca, whose walls consist of the glandular excretory cells of the organ. All the above passages are lined with non-glandular cells. Blood entering the branchial heart, fills the passages excavated in its walls, some of which extend into the substance of the adjacent pericardial gland. The blood thus comes into contact with the excretory cells of the branchial heart appendage, and is there deprived of waste matter.

NERVOUS SYSTEM.

All Cephalopods have a highly concentrated nervous system, which reaches its maximum in *Argonauta*, *Octopus* and then *Eledone* ranking next in the series. The typical molluscan ganglia are so closely approximated, and so intimately connected, as to form a peri-oesophageal nerve collar, just behind the buccal mass, and between the eyes (Pl. IX, figs. 70 and 76). In *Eledone*, this collar or " brain " is enclosed in a tubular cartilaginous capsule, the anterior and posterior ends of which are closed by tough membranes. These are pierced for the passage of the oesophagus, posterior salivary duct, pharyngeal arteries, &c. (Pl. X, figs. 85*a* and *b*, and 82, *P.M.*). Round the brain, and separating it from the cranial walls, is found a kind of gelatinous transparent tissue.

Four pairs of ganglia, the cerebral, the brachial, the pedal, and the visceral ganglia, form the brain of Eledone. These pairs of ganglia are, however, very intimately fused together, and although the supra-oesophageal or cerebral ganglia are distinguishable from the remaining sub-oesophageal ganglia, yet the three pairs which build up this latter mass cannot be definitely marked off externally one from another. Similarly any two ganglia of a pair are intimately fused, so as to appear like one mass only. The ganglion cells in these ganglia form an external layer round a central fibrous mass.

The Cerebral ganglia form a supra-oesophageal mass oval in dorsal view, triangular when seen laterally (Pl. IX, figs. 76 and 70, *C. G.*). Three transverse grooves mark the ganglionic mass externally into four divisions which increase in size from the front, backwards. The last and largest division is marked with longitudinal alternating bands of white and grey matter, and the regions of the above grooves are also grey. The anterior division of this mass also bears a groove running antero-posteriorly, along its dorsal middle line.

The Brachial ganglia form the anterior third of the sub-oesophageal mass. They exceed in size the pedal ganglia, and together with these form a mass which is morphologically equivalent to the pedal ganglia of other Molluscs (fig. 70, *Br. G.*). As the arms are so greatly developed, while the remaining portion of the foot, the funnel, is comparatively small, so the brachial ganglia exceed the pedal ganglia in size. The former are also connected *above* the oesophagus by a slender supra-oesophageal commissure.

The Pedal ganglia form the central and smallest portion of the sub-oesophageal mass, and innervate the funnel (epipodium) (fig. 70, *Ped. G.*).

The Visceral ganglia lie behind the pedal. According to Pelseneer, there are really two pairs of visceral ganglia—an anterior pair (the pleural ganglia) lying dorsally and giving off the pallial nerves, and a more ventral pair posterior to these, which give off the visceral nerves (fig. 70, *Ant. Visc. G.* and *Visc. G.*).

Commissures.—Short stout commissures connect the sub- and supra-oesophageal nerve masses. There are two such pairs, the posterior being the broader:—(1) the anterior pair, uniting the cerebral and brachial ganglia, and (2) the posterior pair, uniting the cerebral and viscero-pedal masses.

NERVES.

From the brain are given off numerous pairs of nerves, which innervate the different regions of the body.

A. The nerves given off from the cerebral ganglia are:—(1) Optic, (2) olfactory, (3) labial (4 pairs), (4) buccal, (5) anterior superior ophthalmic nerves, and the motor nerves of the eyeball.

B. The nerves given off from the sub-oesophageal mass are:—(1) Posterior superior ophthalmic, (2) inferior ophthalmic, and the motor nerves of the eyeball, (3) anterior infundibular, (4) posterior infundibular, (5) visceral, (6) pallial, (7) accessory pallial, (8) anterior vena caval, (9) auditory, (10) brachial, (11) interbrachial, and (12) the nerves of the head.

A. (1) **The Optic nerves** are stout, rather short nerves running straight out from the lateral region of the cerebral ganglion at the level of the posterior groove (fig. 70, *Opt. N.*). In section the optic nerve is oval, and piercing the cranial cartilage it enters the orbit and there expands into a large oval optic ganglion from which are given off nerves to the retina (Pl. IX, fig. 71, *R.N.*). These optic ganglia are each greater in bulk than the two supra-oesophageal ganglia, and are about twice as long as they are thick. Internal to the optic ganglion, on the dorsal side of the optic nerve, is a much smaller oval ganglion (fig. 71, *o.g.*). Chéron termed this the olfactory ganglion, but Zernoff denies its connection with the olfactory organ.

A. (2) **The Olfactory nerves.**—The strands of the olfactory nerve are, at their origin, indistinguishable from those of the optic nerve. They lie ventral to these, however, and run along with them to the optic ganglion. Here they separate, and run on as a separate nerve, which is absolutely independent of and unconnected with Chéron's olfactory ganglion (fig. 71, *olf. N.*). Beyond the separation from the optic nerve it may be seen, running external to the white body, on the internal wall of the orbit (fig. 71, *x.*), where it pierces the wall of the eyeball and then runs over the dorsal posterior wall of the eye to the olfactory pit, which it innervates (Pl. IX, fig. 74, *olf. N.* and *olf. P.*).

A. (3) **Labial nerves.**—These are four pairs of fine nerves, which run out from the anterior edge of the cerebral ganglion and innervate the lip (fig. 76, *a*, *b*, *c*, and *d*). Leaving the cranial cavity, they pierce the membranous wall which closes this cavity anteriorly, and then run over the outer wall of the sinus venosus, which here surrounds the buccal mass, anterior salivary glands, and oesophagus (fig. 76, *S. V.*). Anterior to the sinus venosus, they run over the outer wall of the buccal mass, and so finally reach the lip, where they end in fine branches. The innermost pair of labial nerves (fig. 76, *a*) leave the cerebral ganglion one on each side of the middle line, and running along the outer wall of the sinus venosus, each soon divides into two branches. Reaching the anterior limit of the sinus venosus, each half again gives off several small branches, which end finally in the lip. The second and third pairs have a similar course, the third pair being rather stouter than the second (fig. 76, *b* and *c*). The fourth pair run forwards and outwards over the wall of the sinus. Thus they cross over the buccal nerves which run forwards and inwards (fig. 76, *d*, and *B. N.*). Each of the two gives off two branches, an inner and an outer. The three branches thus obtained now run over the wall of the sinus to end in the lip.

A. (4) **Buccal Nerves.**—These are two nerves much stouter than the labial. Running from the outer anterior angle of the cerebral ganglion each nerve pierces the anterior cranial wall, and then runs inwards towards the sub-oesophageal ganglion (Pl. VIII, fig. 72, *B.N.*). Arriving at the posterior lateral wall of the buccal mass, this nerve divides into three branches (fig. 72, *D.*, *M.* and *V.*). Of these, the most dorsal runs up to the sub-oesophageal ganglion, the median ends in branches in the buccal wall, while the ventral one curves downwards, and ends similarly in the wall of the buccal mass. The innermost branch given off from this ventral nerve runs towards its fellow from the other side and meets it just below the initial part of the radula sac, swelling here to form a small, oval sub-radular ganglion (fig. 72, *r. b.*).

Ophthalmic Nerves.—To see these it is best to expose the eyes from the dorsal surface by dissecting away the skin and superficial muscles from the back of the head (Pl. IX, fig. 74, *E.*). Thus the muscles which dorsally cover the brain case and the bases of the arms are also exposed (fig. 74, b_1 and *a*). There are three groups of ophthalmic nerves on each side:—(1) three anterior superior, (2) one posterior superior, and (3) three inferior.

A. ([illegible]) **The Anterior Superior Ophthalmic** are three fine nerves which arise dorsal to the origin of the optic nerve of the corresponding side (fig. 70 *Ant. Sup. oph.*). The most anterior of these pierces the cranial cartilage and so enters the orbit, and runs for a short time along its inner wall. Then, piercing the muscles of the eyeball, it runs external to this out to the eyelid, where it ends in several fine branches (fig. 74, *Ant. Sup. oph.*). The two posterior nerves are motor only. Piercing the cranial wall, and entering the orbit, they are distributed to the dorsal region of the muscles of the eyeball.

B. (1) **The Posterior Superior Ophthalmic** (fig. 74, *Post. Sup. oph.*) is a rather stout nerve, arising from the postero-dorsal angle of the visceral ganglion, anterior to the pallial nerve (fig. 70). Running outwards, this nerve penetrates the cranial wall and so enters the orbit. Here it runs internally to the wall of the orbit, and external to the white body for a short time, and soon expands into a small oval ganglion. Piercing the muscular wall of the eyeball, it runs over its outer surface (fig. 74, *Post. Sup. oph.*), and finally ends in several branches which are distributed to the eyelid.

B. (2) **The Inferior Ophthalmic** are three nerves on each side, of which the posterior is the least and is purely motor, being distributed to the inferior muscular wall of the eyeball. All three nerves, arising from the lateral face of the sub-oesophageal ganglionic mass, rather in front of the median line, run outwards and enter the orbit after piercing the cranial wall. The anterior nerve, after running for a time on the inner wall of the orbit, pierces this, and then runs along its outer wall to the eyelid, where it ends in several fine branches. The median nerve of the three is the largest and has a course similar to that of the posterior superior nerve. Like this, it bears a ganglion, but runs over the antero-inferior surface of the eyeball (fig. 75, *Inf. oph. N.*).

B. (3) **The Anterior Infundibular Nerve** is given off from the ventral surface of the brain, at about its median point (fig. 70, *Ant. Fun. N.*). It is exterior to the nerve of the anterior vena cava and ventral to the auditory nerve. This nerve pierces the ventral wall of the cranial cartilage (fig. 69) anterior to the statocysts. Between the two anterior infundibular nerves is an oval aperture, through which the two forks of the anterior aorta leave the central cavity of the brain, and reach its ventral surface (see arterial system in Section IV). Just before the nerve leaves the cranial cavity it gives off a fine branch which leaves this cavity by an independent hole, and runs to the protractors of the funnel on that side. After leaving the cranial cavity the anterior infundibular nerve gives off a second branch which supplies the posterior dorsal wall of the funnel. Some of its branches run to the wall of the lateral funnel chamber. Soon after, the nerve gives off a third branch to the funnel. This ends in several branches which run to the median wall of the funnel. The anterior infundibular nerve runs on anteriorly, and soon bifurcates, both halves entering the funnel wall, and both supplying eventually the dorsal wall of the funnel. The lower of these two branches soon swells into an oval ganglion, which is about as large as the smaller of the two ganglia on the course of the visceral nerve. From the anterior end of this ganglion several branches run, with the strands from the upper branch, to the dorsal wall of the funnel. The ultimate fine branches in which all these infundibular nerves end form a complete anastomosing network which quite surrounds the funnel walls.

B. (4) **The Posterior Infundibular Nerve** runs out from the brain just exterior to the corresponding visceral nerve of that side (fig. 70, *Post. Fun. N.*). It is not so stout a nerve as the visceral. Piercing the posterior wall of the cranial cavity, external to this nerve, it runs out to the postero-dorsal wall of the funnel (fig. 69, *Post. Fun. N.*). Next it penetrates the visceral envelope, and runs for a short time on the inner wall of this structure, and then returns to its outer side (Pl. X, fig. 82). Then it runs out to the funnel and innervates its posterior region, splitting into three main forks (fig. 69): (1) A fine anterior strand which running forwards splits up into several branches innervating the funnel wall: (2) a stouter median branch which ends similarly, just behind the above; and (3) a posterior strand, which innervates the depressor muscle of the funnel.

B. (5) **The Visceral Nerves** are very long and stout. Much of their course may be followed by removing the septal muscle, and also the epithelial cover of the visceral mass, as they run over the ventral surface of the liver. The visceral nerve is given off from the posterior surface of the visceral ganglion, at its external and ventral angle (fig. 70, *Visc. N.*). Piercing the membranous posterior wall of the cranium, it reaches the inner surface of the visceral envelope (fig. 82, *Visc. N.*), courses along the inner surface of the visceral envelope, just to one side of the median line, runs over the anterior surface of the liver, and gains its ventral surface. In fig. 69, *Visc. N.*, it may be seen on the ventral side of the visceral envelope, which it has pierced. It is now separated from its fellow by the anterior vena cava, alongside which the visceral nerve runs for some time. Further back the visceral nerves are also separated by the rectum, which lies on the right side of the vena cava (fig. 69, *R.*). At the level of the anterior edge of the kidney, the visceral nerves begin to slope away from one another, each running out towards the branchial heart of its side. This slanting course at first causes them to run external to the kidneys, but more posteriorly they run over the kidney sac (fig. 69), and then passing between the ureter and the oviduct—or penis—they gain the branchial heart, and finally end in the branchial nerve which runs up the fleshy axis of the gill (fig. 69, *Bl. N.*). The visceral nerve swells during its course into two ganglia, of which the second is the larger. The first is a small oval ganglion, just anterior to the ureter. From it radiate fine nerves to the oviduct, coelomic canal, flask-like division of the coelom, and the aorta (fig. 69, *g′*). Two other fine nerves are given off, one running down the surface of the kidney to the wall of the genital capsule, while the outer and smaller nerve ends in the kidney wall (fig. 69). The second ganglion is larger, and is about 3 mm. across (fig. 69, *g″*). It is attached to the cord dorsally, and adheres to the wall of the branchial heart. Branches radiate out from its free edge, to the walls of the lateral venae cavae, and the efferent artery. Several branches are also given off to the substance of the branchial heart, and there is a small anterior branch which runs to the muscles of the back. Two longer branches sink down dorsal to the kidney, and end in the back and the genital capsule respectively. Beyond this ganglion the nerve may be called the branchial nerve. It runs along that side of the gill nearest to the visceral mass, just lateral to the afferent blood vessel (fig. 69, *Bl. N.*). It gradually narrows down with the decreasing size of the gill, and swells to a ganglion at the level of each internal lamella of this organ (fig. 69, *Bl. g.*). Each ganglion gives off a nerve which runs down the gill lamella to which it corresponds, and also a second nerve which runs dorsal to the afferent vessel, and so reaching the external side of the gill feeds the lamella alternating with the internal one. Soon after attaining the ventral surface of the liver, the visceral nerve gives off a large, much-branched nerve to the anterior vena cava. This runs down along the wall of the vessel to about the level where the ink duct enters the visceral mass (fig. 69). A second branch runs out from the main nerve, over the visceral envelope, and ends in small branches to the depressor of the funnel. On its way, this nerve gives off several branches to the visceral envelope, and while that of the right side furnishes a long branch to the bent region of the intestine, that of the left sends a fine branch to the rectum (fig. 69). The visceral nerve, during its course over the liver, gives off many fine branches to that organ, to the ink sac, to the kidney wall, &c. Nerves may also be seen running to the rectum and the septal muscle.

B. (6) **The Pallial Nerve** is a broad flat nerve given off from the posterior dorsal angle of the anterior visceral ganglion (fig. 70, *Pall. N.*). Running posteriorly and outwards, it pierces the membranous posterior cranial wall, and so enters the visceral sac (fig. 82). On entering the visceral sac it runs outwards and posteriorly along the inner wall of the visceral envelope, towards the great lateral muscle, giving several branches to the envelope in its course. Then it runs obliquely through the lateral muscle, to terminate in a large flat triangular star-shaped mass just exterior to this muscle. This "stellate ganglion" controls the movements of the mantle, on the inner surface of which it lies, covered by the internal epithelium of the mantle. In an adult *Eledone* the ganglion is about 6 mm. across, and its surface is smooth. It gives off a radiating series of nerves to the mantle. These nerves are all stout, and after running for part of their course on the internal wall of the mantle enter its substance, and divide up into smaller branches, which end there, forming a network of nerves throughout this organ. There are about fourteen of these large branches, and also several short nerves which run directly inwards into the mantle substance from that surface of the stellate ganglion which is applied thereto. The two longest radiating branches run down towards the base of the gill, and innervate the posterior part of the mantle (fig. 69). Internal to these longer nerves are two shorter ones which run below the lateral muscle, and then enter the mantle.

B. (7) **The Accessory Pallial** is a rather more slender nerve, given off just dorsal to the pallial (figs. 69 and 70, *Acc. Pall. N.*). It pierces the cranial wall dorsal to the pallial nerve, and runs alongside this for a short time, on the inner surface of the visceral envelope. Next it runs inwards and becomes embedded in the muscles of the head. Here its fibres may be traced to the lateral wall of the funnel and also to the great lateral muscle.

B. (8) **The Nerve of the Anterior Vena Cava** arises just exterior to and behind the anterior funnel nerve (fig. 70, *Ant. V. N.*). It is a fine nerve which, after piercing the ventral wall of the cranial capsule, curves ventrally round the wall of the anterior vena cava (fig. 69), and ends in several fine branches.

B. (9) **The Auditory Nerve** is short and slender, and runs to the auditory organ or statocyst, from its point of origin, just above the anterior funnel nerve (fig. 70, *Aud. N.*). Each auditory nerve running posteriorly enters the statocyst at its interior and dorsal angle, and then runs to the membranous vesicle, ending in two branches, one to the sensory pad and the other to the sensory ridge in that organ. In reality the fibres of the auditory nerve arise from the cerebral ganglion (Pelseneer).

B. (10) There are eight **Brachial Nerves** given off from the anterior edge of the brachial ganglion (fig. 70, *Br. N.*) which run forwards over the buccal mass, towards the bases of the arms. They run on the outer side of the wall of the sinus venosus and may be seen there as broad flat bands. Between the above wall and these brachial nerves lie the labial nerves, dorsally. Each brachial nerve runs up the centre of an arm, internal to the corresponding brachial artery, and lessening towards the tip of the tapering arm (Pl. IX, fig. 69, and Pl. VIII, fig. 80, *Br. N.*). At the base of the arms, in the region where they are joined on to the cephalic mass, a circular nerve cord joins the eight brachial nerves together (figs. 69 and 80, *N.Circ.*). This cord is of very peculiar structure. Between the nerves it is single, but in the region of the nerves it splits into two cords, of which the anterior joins on to the brachial nerve, while the posterior runs below it (fig. 69). Running up the arm the brachial nerve bears a series of long elliptical ganglia on its oral surface (Pl. IX, fig. 77, *S.G.*). Each ganglion corresponds to a sucker, and gives off two rows of small nerves which run up to innervate these structures (fig. 77, *S. N.*) and also the muscles of the arm. A gelatinous transparent tissue fills the space between the nerve cord and the walls of the cavity containing it.

B. (11) **Interbrachial Nerves.**—Several small nerves given off between the ventralmost brachial nerve and the one above this run out and innervate the bases of the arms. Also between the second and third, and the third and fourth brachial nerve, counting upwards from below, a fine nerve runs out to these muscles (fig. 70, *I.br.*).

B. (12) **Nerves of the Head.**—Just above the dorsalmost brachial nerve, at its origin, a fine nerve on each side runs outwards to innervate the muscles of the head (fig. 70, H_1).

Visceral Nervous System.

Eledone, like all other Cephalopods, possesses a visceral nervous system. There are two ganglia, one situated near the anterior end of the alimentary canal, and one near the stomach. The two are united by a long nerve which runs down the wall of the oesophagus. Each of them gives off several nerves to the neighbouring parts of the alimentary canal. This system is connected with the central nervous system by means of the buccal nerve *only*.

The Sub-oesophageal Ganglion represents the anterior centre of the visceral system (fig. 72, *Oes. g.*). It is a fairly large, bilaterally symmetrical, flattened ganglion, situated in the acute angle between the buccal mass and the oesophagus. To expose it properly, the anterior salivary gland must be turned forward (Pl. VIII, fig. 72, *s. g.*). Looked at laterally, the ganglion is roughly triangular. The buccal nerves enter it at its posterior external angles (fig. 72, *B. N.*). From the anterior angle the ganglion gives off several nerves. Of these, the lowest enters the buccal mass, the next runs to the anterior salivary gland (fig. 72, *a* and *b* resp.), the third enters the buccal mass (fig. 72, *c.*), the uppermost (fig. 72, *d.*) runs up to the oesophagus, and then anteriorly along its wall to the buccal mass. The posterior edge of the sub-oesophageal ganglion gives off two nerves to the oesophagus. The anterior one is short (fig. 72, *f*), but the posterior one is long and runs down the side of the oesophagus as far as the crop (fig. 72, *g*). Posterior to the crop the left and right nerves of this pair join, and then this nerve runs along the ventral side of the oesophagus down to the gastric ganglion. These two nerves give off branches to the oesophagus all along their course, and specially important ones alongside the crop.

The Gastric Ganglion is the posterior centre of the visceral nervous system, and lies on the ventral surface of the alimentary canal, just where the intestine and spiral caecum lead out of the stomach. It is triangular, about the size of a wheat grain, and is exposed on turning forward the liver (Pl. V. fig. 38 *a*, and Pl. IX. fig. 73, *G. g.*).

A. From its right upper corner it gives off:—(1) A large nerve which runs up over the ventral surface of the posterior part of the oesophagus, giving off several branches to the wall on its way (fig. 73, *a*), continues its course along the oesophagus, and ends in the sub-oesophageal ganglion as previously described; (2) several short branching nerves to the base of the oesophagus, and to the ventral wall of the stomach (fig. 73, *b*); (3) a large nerve which runs along the groove marking the division between oesophagus and stomach, and gives off small branches on its way, ending by running round the right side of the stomach to its dorsal border (fig. 73, *c*).

B. From the left upper corner are given off:—(1) A large intestinal nerve which runs along to the anus (fig. 73, *e*); (2) several small nerves which end in the walls of the initial part of the intestine (fig. 73, *f*).

C. From the third and lowest angle of the gastric ganglion are given off:—(1) Several branching nerves to the spiral caecum (fig. 73, *g*); (2) two large and several smaller nerves to the paired hepatic ducts (fig. 73, *h*). These run upwards into the liver.

The large intestinal nerve, from analogy with *Sepia*, gives off a fine branch to the ink gland at the level where the ink duct enters the intestine. It has not, however, been followed in *Eledone*. From the posterior edge of the gastric ganglion are given off several small nerves to the initial part of the intestine and spiral caecum, and also a large branching nerve to the postero-ventral wall of the stomach (fig. 73, *d*).

SENSE ORGANS.

The general surface of the body of Eledone is sensory, the arms in particular forming slender sensory organs. There are, in addition, well developed eyes, organs of equilibration—the statocysts, and the olfactory organs which probably function also as taste organs.

The Eye.

Eledone has a pair of prominent eyes, situated one on each side of the head (Pl. I, fig. 1, *E.*). As in the case of most Cephalopods, they are sessile. In large specimens of *E. cirrosa* the diameter of the eye is about 25 mm. Although it much resembles the vertebrate eye in several respects, i.e., both are vesiculate and both are very complex and remarkably perfect in structure, yet there are many profound differences. The eye of Eledone has no anterior or aqueous chamber, no choroid, and the cells of the retina are different from those of the vertebrate retina. Again, while the Vertebrate has a cerebral eye, that of Eledone originates as an invagination of the epidermis, which later becomes elaborated into retina, iris, &c. Another important point upon which they differ is that while in vertebrates the optic nerve penetrates the retina and enters the retinal cells from the front, in the Cephalopod the fibres of the optic nerve enter the retinal cells from behind and do not pierce the retina.

The circular external orifice of the eye is small, only about 6·5 mm. in diameter, and is surrounded by the skin of the head, and the muscular sheet which binds the cephalopedal mass together and to the mantle, superficially (Pl. X, figs. 83 and 84, *ext. or.*). This circular rim round the eye forms an eyelid which can completely close over that organ by radial contraction. Dorsally this eyelid is continued over the aperture of the eye as a membranous semilunar transparent fold (Pl. X, figs. 83 and 84, *ps. ext.*). Ventrally another fold is continuous with the eyelid, this fold also being transparent, but lying below the dorsal one mentioned above, and extending further over the eye (figs. 83 and 84, *ps. int.*). These two membranes appear to be only slightly if at all moveable, and through them may be seen the pupil of the eye (Pl. X, fig. 78, *ps. mem.*). Possibly water may penetrate between them and so bathe the lens directly, as in the Oegopsida. These two membranes may be called the external and internal pseudocorneal membranes, the internal being the thinner. Cutting away these two membranes, the metallic deeply pigmented iris is exposed; this iris bounding an oval pupil (fig. 78, *Iris*) which it opens and closes by a dorso-ventral expansion or contraction. Text fig. V shows the various stages of contraction and expansion which occur in the eye of Eledone. When resting, the eye seems to vary from (*a*) to (*d*) without apparent cause. Stage (*a*), however, seems to occur after a rest of long duration, i.e., it is noticed when examining Eledone early in the morning. Stage (*e*) shows the eye opened much more widely, as it is when the animal is disturbed, and (*f*) shows the condition during periods of great fright or agitation.

Looking into the pupil the lens can be seen. This is a spherical ball, built up of concentric layers of a non-cellular, transparent, cuticular, crystalline substance (fig. 78, *L*). Looking down into the pupil the eye appears black, because the dark retina shows through the lens, from behind.

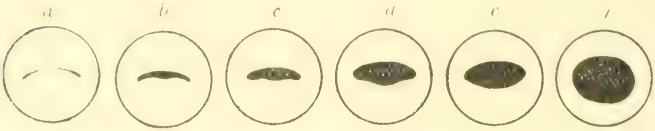

Fig. V. Eye of *E. cirrosa*, showing various stages of dilatation of pupil. × 2.

The eye is enclosed in a cartilaginous cup, that adheres internally to the "skull." This cup is thickest at the base but much thinner at its external edge, which reaches about half-way round the eye (fig. 85 *a*, *orb. C.*). External to the capsule a strong muscular coat is attached which surrounds the eye and extends as far as the lid (fig. 78, *Ext. Musc.*). Internal to the capsule is a second muscular coat, which extends to the border of the pupil, and is more delicate than the first (fig. 78, *Int. Musc.*). The retina, sclerotic, &c., form a roundish, rather depressed chamber that only occupies about one-third of the whole volume of the eye. Behind this chamber is a second much larger one that contains the optic ganglion, which gives off from its external surface a great number of nervous strands to the retina, and the white body (fig. 78, *Opt. G.* and *W. B.*).

The white body is a glandular mass surrounding the optic ganglion, and consists of three lobes—one large dorsal and two smaller ventral (Text fig. VI). This body has been shown to be the remains of a degenerate portion of the embryonic nervous system, and possibly is the seat of formation of the blood corpuscles. This, however, is doubtful, as its blood supply, from the arteries of the eye, is very limited. The skin which covers the eyelid, after being reflected over the pseudo-corneal membranes, is continued down the inner surface of the external muscular coat of the eye (fig. 78, *Conjunct.*). Just anterior to the cartilaginous capsule it is reflected on to the globe of the eye, and running up clothes the iris as far as the pupil. Here it is again reflected internally and runs down on the internal surface of the iris, and then over the ciliary body, and then is continued as the external layer of the true cornea. This outer layer of the two-layered cornea thus arises from the infolded external skin of the head, while the internal layer is the external part of the wall of the optic vesicle, of which the internal part forms the retina. Hence the internal layer of the cornea and the retina are continuous. The two corneal membranes secrete the lens which thus is in two segments, an external smaller one and a larger internal. The external division is a segment of a much larger sphere than is the internal, but the two themselves are of equal area where they adjoin the cornea. They readily separate. The internal segment alone corresponds morphologically with the Gastropod lens. The rest of the ocular cavity is occupied by the vitreous body—a thick, perfectly clear and transparent fluid, contained in a thin membranous sac

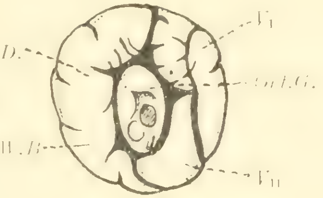

FIG. VI. Diagram showing relation of white body to eye and optic ganglion. × 1.

fig. 78, *Vitr.*). The white body and optic ganglion are also contained in a thin-walled sac, which encloses a venous blood sinus—this blood, therefore, bathing these organs.

The optic vesicle is covered posteriorly by a tough semi-cartilaginous sclerotic (fig. 78, *Scl.*). This is iridescent, and reaches to the external border of the ciliary body, which supports the lens. Posteriorly it is pierced by numerous fine holes, which allow the passage of optic nerve strands to the retina. The internal wall of the iris is very darkly pigmented, and raised anteriorly into a circular ridge. While arterial blood is supplied to the eye by two arteries which are given off by the anterior aorta soon after bifurcation, the venous blood is drained off into the above-mentioned venous sinus, and thence passes by a vein through the ventral wall of the skull to the anterior vena cava. As in all Cephalopods, the eye may be adapted for near and distant vision by variation of the distance between the lens and the retina.

The Retina is the most complex part of the eye of *Eledone.* Anteriorly it is continuous with the ciliary body and internal layer of the cornea, and it forms the posterior wall of the optic vesicle. It is very deeply pigmented with a dark brown retinal pigment. Grenacher and Hesse made very careful examinations of the retina of *E. moschata.* The structure (as given by Hesse) of this retina appears to agree with that of *E. cirrosa,* except in one point, which will be mentioned below. The retina consists of a single layer of cells (see Pl. X, fig. 86), which are of two kinds, *retinal* and *limiting* cells. The former are long slender cells, alternating in position with the rather shorter limiting cells (Pl. X, fig. 86, *Ret. C.*; *Lim. C.*). There are three regions in the retinal cell:
(1) The innermost and longest region, where the rods are situated (fig. 86, *Rod.*); (2) the central shortest region,

where most of the characteristic dark brown retinal pigment is collected (fig. 86, *Pig.*); and (3) the basal region, which is external to the basal membrane, and is continued outwards into fine nerve fibres continuous with the nerve cells of the optic ganglion. The nucleus also is found in this region (fig. 85, *Opt. N. f.*; *Ret. N.*).

There are two long slender cuticular rods in each retinal cell. These are crescentic in cross section, and enclose between them the cytoplasm of the cell. By making a cross section of the retina, i.e., at right angles to the length of the cells, it will be seen that the rods are arranged in groups of four, all four belonging to adjacent but separate cells. Hence the two rods of any cell belong to adjacent groups of four rhabdomes.

The limiting cells lie between the visual or retinal cells. They are broadest at the base, and the roundish nucleus is situated here. Also in this region there is an accumulation of pigment granules, corresponding to that in each retinal cell (Pl. X, fig. 86, *Lim. N.*). The limiting cells are shorter than the visual cells, and end just internal to the basal membrane (fig. 86, $B_1 M_1$). This is a membrane of connective tissue, external to the limiting cells therefore, but pierced by the retinal cells. The region below this membrane and between the basal part of the visual cells is occupied by connective tissue and blood vessels (fig. 86, *C. T.*). In the region where the rods are found the limiting cells extend forward only as very fine protoplasmic processes (fig. 86, $Lim_1\, C_1$), which are continued as far as, and secrete, the membrana limitans, which covers the internal surface of the retina (fig. 86, *M. L.*).

Hesse has observed in *E. moschata* a fine, somewhat sinuous fibre which runs centrally down each retinal cell, from the basal region, and ends in a minute knob at the tip. This fibre and knob he considers to be the termination of the nerve in the retinal cell. This continuity has, however, not yet been seen in *E. cirrosa.*

There is in both species a second region where pigment accumulates, towards the internal end of the retinal cell (fig. 86, *Pig*$_1$). The pigment here is connected with the larger basal accumulation by a long slender track. This track and internal accumulation surround the nerve fibre and knob, according to Hesse.

In the dark, e.g., at night, the pigment all collects at the base of the cells, but during the daylight much flows up from here, and collects at the apex of the cells, and so protects the delicate visual cells from excess of light.

The Olfactory Organ.

Eledone has one pair of olfactory pits. These are round, of about 3 mm. diameter, and situated just inside the mantle cavity, in the angle between the postero-lateral wall of the funnel and the mantle. Hence they cannot easily be seen in the living specimens. They are shallow pits, lined by horizontally folded epithelium (Pl. X, fig. 66, *olf. P.*).

The epithelial lining consists of two kinds of tall slender cells:—(1) Spindle shaped cells with large nuclei, which are the true olfactory cells, each bearing externally a stiff fine process, while internally they are continued into fibres which run from the olfactory nerve, and having, external to the nucleus, an oval, finely granulated body (Pl. VI, fig. 65, *Olf. cell*). (2) Epithelial cells, of long cylindrical form, which are interspersed among the sensory cells (fig. 65, *Ep. cell*), and have their internal ends drawn out into fine branching processes.

We have no evidence that this organ is really olfactory in function. More probably it is some kind of taste organ. Its function may be the testing of the water which enters the branchial cavity.

The Auditory Organ.

Eledone has one pair of statocysts, embedded in the ventral wall of the cranial cartilage, and therefore just below the sub-oesophageal nervous mass, between the pedal and visceral ganglia. The membranous statocyst is spherical, with a diameter of 6 mm., and lies in a spherical cavity of somewhat larger dimensions. The organ is attached to its cartilaginous capsule by a network of fine arterial vessels, running to the wall of the vesicle (Pl. VIII, fig. 68, *Aud. caps.*, *Aud. ves.*). The venous blood collects in the cavity of the capsule, and thence passes out to the anterior vena cava, along with the blood from the eye. Dorsally the smooth cartilaginous wall is pierced by the auditory nerve and artery. Internally a thin wall separates the two capsular cavities.

The Statocyst itself is a spherical transparent structure, lined with a flattened epithelium. Its antero-dorsal wall is thickened into an oval pad, whose internal wall is covered with columnar cells, bearing numerous short cilia (fig. 67, *s. d.*). Besides this sensory pad, there is also a sensory ridge, which runs from the former round the dorsal wall of the vesicle, then over the ventral, and finally ends on the dorsal surface (fig. 67, *s. r.*). Between these two sensory regions is a low conical ridge which projects inwards from the wall of the vesicle (fig. 67, *pr.*).

The auditory nerve originates in the cerebral ganglion, runs downwards, and leaving the pedal enters the statocyst dorsally, and bifurcates. One branch ends in the pad, whereas the other supplies the ridge, which is composed of two longitudinal rows of columnar ciliated cells.

The cavity of the vesicle is filled by a clear transparent fluid. Fitting on the pad internally is a small conical calcareous statolith (fig. 67*a*, and 67, *Stat.*), which is probably secreted by the cells of the pad.

The function of the statocyst is that of equilibration. Experiments in other Cephalopods have shown that destruction of one or both statocysts causes loss of power to balance properly in the water. The description given by Owsjannikow and Kowalevsky of the statocyst of *Octopus* agrees with this organ in *Eledone*. Kölliker has shown that the short blind finger-like canal, running outwards from the wall of the vesicle near the sensory ridge (fig. 67, *K. C.*), is the ciliated remnant of the invagination which gives rise to the auditory pit, seen in the embryos of Cephalopods.

REPRODUCTIVE SYSTEM.

I. FEMALE.

The Ovary occupies the posterior end of the visceral dome. It is a large organ, the size varying with the season, and with the maturity of the specimen. When enlarged, the ovary pushes the kidneys which before partially overlaid it forwards and to one side, thus separating them posteriorly (Pl. V, fig. 37, *G.* and *R. K.*).

The gonad is a whitish oval gland, with a thick tough wall. The ventral region of this wall alone bears the ova, which are suspended from it in racemes. Hence the germinal epithelium of the ovary is confined to this ventral region. There are from 30 to 40 racemes of ova (Pl. V, fig. 39, *ov.*). Elsewhere the wall of the ovary is smooth, with the exception of a much folded and twisted patch, situated in the middle line (fig. 39, *gldr. p.*). Here there is a thickened region, intersected by many sinuous lines. Above the oviducal apertures the patch is trilobed, while below them it is bilobed and much larger. This raised and folded region forms a frill round each oviducal aperture, the two being separated by a folded ridge (fig. 39, *c. r.*). There are two symmetrical, equally developed oviducts, through which the ova pass from the genital gland to the exterior. They open into the dorsal wall of the genital gland by two closely approximated apertures, one on each side of the middle line (Pl. V, fig. 39, *l. od. ap. int.*). The initial part of their course is best followed by turning aside the ventral wall of the ovary, together with the ova. The oviducts are embedded in the substance of the dorsal wall of the ovary for some distance beyond their origin, and are hence obscured externally (fig. 39, emb_1). It will be seen that the water vascular canals are similarly embedded in the wall of the ovary for the first part of their course. On reaching the lateral wall of the ovary the two pairs of tubes become free and run round the side of the genital gland to its ventral surface. From this point the oviduct slants obliquely forwards and outwards, dorsal to the kidney, and at the level of the ureter reaches the ventral surface of the visceral mass. About half-way down the duct occurs a whitish oval swelling—the oviducal gland. As shown in fig. 8, the terminal third of the oviduct is visible from the mantle cavity, being only covered by the epithelium of the visceral mass.

All the eggs in any given ovary are at the same stage of maturity. The origin of the ova has not been followed in *Eledone*, and the youngest specimens examined already show the eggs well developed, and surrounded by a nourishing egg follicle. In other Cephalopods the ova are cells of the germinal wall, which sink below the general epithelium, and then protrude into the ovary, pushing the wall before them until they are completely surrounded by an epithelial layer, several cells thick. The egg itself becomes surrounded by a special nourishing or follicular layer, at the expense of the surrounding cells. With the growth of the ovum, this layer becomes actually folded into the egg substance (Pl. IX, fig. 67*b*, *foll.*), to increase its surface of contact with the ovum. Further protrusion and folding of the germinal wall gives rise to the characteristic racemes (Pl. V, fig. 41, *egg. R.*). Finally the follicle secretes the chorion round the mature ovum, which now escapes, bursting through the covering layers (fig. 67*b*, *C. T.*), and then passing out by the oviduct.

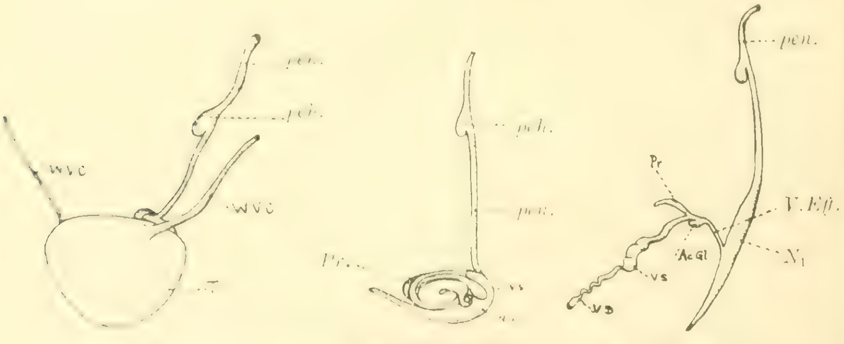

Fig. VII.—A.　　Fig. VII.—B.　　Fig. VII.—C.

Fig. VII. Male reproductive organs of young *E. aldrovandi*. A, from ventral side; B, genital duct as in situ, dorsal view; C, genital duct unravelled to show various regions; × 2.

II. Male.

It is not proposed to give a detailed account of the male genital organs of *Eledone*, as no male specimen of *E. cirrosa* could be obtained. However, the following description of an immature male *E. aldrovandi* will probably resemble *E. cirrosa* in its general outlines. As in the female, the genital gland is situated posterior to the alimentary canal, at the extreme end of the visceral dome. It is rounded in shape and opens to the exterior by:—(1) Two coelomic canals, right and left, which open anteriorly into the testes (Text fig. VIIA, *W. V. C.*); and (2) one sexual duct, which is the left, the right being atrophied. The hinder portion of this duct is coiled into a spiral mass lying on the left antero-dorsal wall of the genital gland (Text figs. VIIA and B.). The different regions into which it is divided when spread out are shown in Text fig. VIIc. Much of this duct is ciliated internally. The part visible from the mantle cavity resembles in position and appearance the left oviduct of the female (Pl. II, fig. 8, *pen.*).

A narrow winding vas deferens leads off the spermatozoa from the testes (Text fig. VIIc, *V. D.*), and then widens to form the vesicula seminalis. This region and the prostate and accessory glands are concerned in the formation of the spermatophores, i.e., they form a tube round the spermatozoa (Text fig. VIIc, *V. S.*, *Pr.*). Needham's sac (Text fig. VIIc, N_1), into which the spermatophores now pass by a short thin vas efferens, is a store, where they are arranged side by side longitudinally, to await expulsion through the penis. As in the ovary of the female, the ventral wall of the testis is alone germinal.

SPAWNING.

The eggs examined were spawned by a specimen of *E. cirrosa* in a tank at Plymouth in July, 1903. Since the crabs placed in the tank as food for the Eledones attacked the ova, only two bunches were saved. The ova have not, as yet, been dredged, or taken in the trawl—possibly they are fastened by the mother amongst rocks in inaccessible places.

The ova of *E. cirrosa* are grouped in characteristic strings during the spawning (Pl. I, fig. 2). One female deposits about 30 of these racemes, each consisting of 25 to 30 eggs, so that the total number spawned is about 800. The whole process of spawning lasts over several days, the racemes being produced at intervals during this time. According to Joubin, *E. aldrovandi* will devour its own spawn if disturbed during the laying process.

The spawn will now be described, so that the order of events in spawning may be understood. The egg itself is enclosed in a semi-transparent horny egg case (fig. 2, *h. c.*), which is secreted by the follicular epithelium before the expulsion of the ovum. Anteriorly this egg case is drawn out into a string for attachment (*egg. st.*). These strings seem first to be twisted together in groups of four to six, and then the latter become intertwisted, thus forming a main central horny axis, which is coated externally by a thin dark layer of horn, and ends in a flat disc which adheres to the glass front of the tank (fig. 2, *A. D.*). The strings of ova are generally attached on or near the glass front of the tank, about a foot from the surface. The actual deposition of the eggs has been observed at the Port Erin Biological Station by Mr. Gravely, of Manchester University, who has kindly furnished me with notes on the process for this Memoir.

For about two hours before the eggs were spawned, the *Eledone* was seen clinging to the glass front of the tank, with the small suckers on the proximal part of the arm extended. Several very violent waves of contraction passed over the body from behind forwards, and several jets of water were directed by the funnel over the proximal region of the arms and the mouth. The dorsalmost pair of arms was loosely thrown back over the head, and while the ventralmost was pressed against the ventral posterior part of the body, the lateral pairs were thrust into the mantle cavity, and appeared to press vigorously against the visceral mass. Then the arms were all twisted about in the water in an extraordinary spiral manner. After these preliminary indications of great excitement, and preparation for spawning, the Eledone seemed to settle down, the small circumoral suckers were approximated and extended so as to form a closed chamber over the region of the mouth. Then the siphon was inserted into this chamber, and a number of eggs passed in. Next the circumoral suckers began to press the very sticky glutinous substance which accompanied the ova against the glass.

The proximal part of the bunch of eggs, together with the adhesive disc, could now be seen, but the distal part of the bunch was still hidden by the bases of the arms. Next the suckers in this region moved the eggs about and appeared to arrange them in their final condition as described above. When first spawned the eggs have no definite central cord, but appear to be held together merely by the glutinous mass which accompanies them. Then the two ventral arms press the bunch firmly against the glass, and seem to test the firmness of the adhesion. The whole process, after the *Eledone* comes to rest before spawning, occupies from fifteen to twenty minutes.

Eledone very rarely spawns when in captivity—possibly as a result of living under artificial conditions. Hence the fact that it is never kept in aquaria throughout the winter may possibly be explained as the result of becoming egg-bound, as well as of too low a temperature.

At Port Erin, *Eledone* frequently appears to make unsuccessful attempts to spawn, and in the late summer the body swells up greatly and then begins to degenerate, causing death. Possibly this may be due to the absence of males.

The large ova of *E. cirrosa* are oval, and slightly narrower at the tip than at the base, measuring about 19 × 6·5 mm. A large amount of yolk is present, in fine granules. The only egg envelope, or chorion, is transparent and horny, being drawn out into the attaching string anteriorly. At this end also it is pierced by the fine micropyle. The ovum is surrounded by a clear fluid, and the formative protoplasm is aggregated at the anterior end, and round the circumference of the egg cell. No vitelline membrane is present, the follicular epithelium in the ovary secreting the chorion.

During fertilisation it is probable that the male, as in *Octopus*, deposits the spermatophores by means of the hectocotylised arm, in the anterior end of the oviducts. When these spermatophores burst, the free spermatozoa enter the eggs by means of the micropyle. As *Eledone* has no nidamental glands, the egg is not covered by any capsule such as occurs in the case of *Sepia*, or jelly mass as in the egg of *Loligo*. Since in *E. cirrosa* the egg is even larger and more yolk-laden than in *Sepia*, possibly the development may be along similar lines.

No account of the development of *E. cirrosa* can be given, as no living material was obtained, nor has the development of any member of the genus *Eledone* yet been followed out. Drawings of two embryonic stages of *E. aldrovandi* are shown on Plate I. Figure 3 is that of a rather younger embryo than is fig. 4 (after Korschelt), and is drawn from some half-developed embryos kindly given by Mr. E. S. Russell, of Glasgow University.

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EXPLANATION OF PLATES.

REFERENCE LETTERS.

a. = Base of arm.
a_1 = Arm tip.
an. = Anus.
an. l. = Anal appendage.
ap. int. = Opening of water canal.
au. = Auricle.
au. v., $au_1\ v_1$ = Semilunar valves.
A_1 = Artery of Br. filament.
A_2, A_3, A_4 = Arms.
A and D. = Anterior and dorsal.
A. D. = Adhesive disc.
A. V. C. = Anterior Vena Cava.
Abd. A. = Abdominal Aorta.
Abd. V. = Abdominal Vein.
Ac. Gl. = Accessory gland.
Acc. Pall. N. = Access. Pallial nerve.
Aff. v. = Afferent Branchial vessel.
Ant. A. = Anterior Aorta.
Ant. Fun. N. = Ant. Infundib. nerve.
Ant. Sup. oph. = Ant. Sup. Ophth. nerve.
Ant. V. N. = Nerve of Ant. Vena Cava.
Ant. Visc. G. = Pleural ganglia.
Arm. A. = Brachial artery.
Arm V_1, *Arm* V_2. = Brachial veins.
Aud. caps. = Auditory capsule.
Aud. N. = Auditory nerve.
Aud. ves. = Auditory vesicle.
b. = Degenerate ovum.
b_1 = Muscles over Cranial Cartilage.
b. s. = Blood sinus.
Br. app. 3. v. r. = Brachial appendage.
Br. mem. = Branchial membrane.
B. A. = Buccal artery.
$B_1\ M_1$ = Basal membrane.
B. M. = Buccal mass.
B. N. = Buccal nerve.
B. V. = Blood vessel.
Bl. A. = Branchial artery.
Bl. N. = Branchial nerve.
Bl.g. = Branchial ganglion.
Br. A. = Brachial artery.
Br. app. = Pericardial gland.
Br. G. = Branchial ganglion.
Br. gld. = Branchial gland.
Br. gld. V. = Vein of Bran. gland.
Br. ht. = Branchial heart.
Br. M. = Branchial muscle, attaching gill to mantle.
Br. N. = Brachial nerve.
Br. V. = Interbrachial vein.

C. = Cuticular layer.
C. A. = Cephalic artery.
C. G. = Cerebral ganglion.
C. N. S. = Central nervous system.
C. S. = Cartilaginous Stylet.
C. cell. = Cartilage cell.
C_1. = Central tooth of radula.
Ceph. V. = Cephalic vein.
circ. m. = Circular muscle.
Conjunct. = Conjunctiva.
Cor. V. = Coronary veins.
C. T. = Connective tissue.
Cr. C. = Cranial Cartilage.
c. r. = Ridge betw. oviducal. apert.
ch. = Chitinous lining.
Chr. = Chromatophores in dermis.
Cil. B. = Ciliary body.
circ. lid. = Circular eyelid.
Coel. = Pericardial coelom.
coll. = Collar muscle.
cr. = Crop.
Cor. A. = Coronary artery.
Cpdl. mass. = Cephalopedal mass.
Cut. L. = Cuticular lining of oesophagus.
depr. = Depression for spermatophores.
D. = Dermis.
D_1 = Dorsum of heart.
D. M. and V. = Buccal nerve branches.
Du. = Salivary ductule.
E. = Eye.
Eff. A. = Efferent artery.
egg. R. = Egg raceme.
egg. st. = Egg stalk.
emb. = Embryo.
emb_1. = Part of oviduct.
e. m. = Muscular septum.
ep. = Epipodium.
Ep. cell. = Epithelial cell.
Ep. = Epidermis.
Ep. S. = Stylet sac.
Ex. C. L. = Ext. fibrous layer.
Ext. = Ext. musc. of sucker.
Ext. Musc. = Ext. musc. coat of eye.
ext. or. = Ext. orifice of eye.
f. = *Foot.*
f_1, f_2, f_3. = Folds of gill fila'ts.
f. ant. = Ant. funnel opening.
f. cl. = Closed funnel (inspiration).
f.o. = Funnel organ.
f. op. = Open Funnel (expiration).
foll. = Follicular layer.

F. = Funnel.
F_1 = Oviducal artery.
F. A. = Infundibular artery.
F. D. = Depressor muscle of funnel.
F. V. = Infundibular veins.
F. W. = Folded wall, olf. pit.
g. = Gill
gr. = Groove for spermatophores.
g′, g″. = Ganglia on Visceral nerve.
gr_1 = Groove betw. web and lip.
G. = Genital gland.
G. A. = Genital aorta.
G. g. = Gastric ganglion.
gldr. p. = Glandular region
G. V. = Genital vein.
gld_1 = Indifferent cells.
h. = Head.
h. ap. = Hepato-pancreatic aperture.
h. c. = Horny egg-case.
H. E. = Epithelial covering of hepatic gland.
Hep. A. = Hepatic artery.
H_1 = Nerves to head.
H. = Heart.
H. V. = Hepatic vein.
H. D. = Common Hepatic duct.
i. d. = Ink duct.
int. = Intestine.
i. s. = Ink sac.
I. br. = Interbrachial nerves.
I. C. L. = Internal fibrous layer.
I. p. = Ink duct papilla.
Irid. = Iridocysts in dermis.
I. S. A. = Artery to Ink sac.
I. S. Gr. = Ink sac groove.
I. S. N. = Nerve to Ink sac.
I. S. V. = Vein to Ink sac.
Inf. oph. N. = Infer. Ophth. nerve.
Int. A. = Intestinal artery.
Int. ap. = First part of intestine.
Int. Musc. = Inter. musc. of eye.
Int. V. = Intestinal veins.
I. E. = Iridescent envelope.
i. ep. = Inter. epith. of oesoph.
I. gld. = Ink gland.
J_1 *and J.* = Ventral and dorsal jaws.
K. C. = Kölliker's canal.
l. = Lip.
l_1 = External lip.
l. d. c. = Left dorsal cirrus.
l. b. s. = Larger blood sinus.
l. f. r. = Left funnel ridge.
l. h. d. and r. h. d. = Hepatic ducts.
lid. = Eye lid.
l. m. gr. = Left mantle groove.
l. od. ap. int. = Int. apert. of l. oviduct.
L. = Lens.
L_1 = Branchial leaflets.
Lac. = Apertures in wall betw. S_2 V_2 and S_3 V_3.
Liv. = Liver.
L. acc. = Accessory gill leaflets.
L. Au; *R. Au.* = L. and R. auricles.
L. Bl. A. = Left Branchial artery.
L. F. D. = Left Funnel depressor.
L. F. Pr. = Left Funnel protractor.
L. M. = Lateral muscle.
L. Pall. A. = Left Pallial artery.
L. V. C. = Lateral Vena Cava.
Lim. C. = Limiting cell.
Lim. N. = Nucleus of ditto.
m. = Mouth.
m_1, *m.l.*, *m.p.*, *m.p. ex.* = muscular sheets.
m. cl. = Mantle closed (expiration).
m. op. = Mantle open (inspiration).
m. s. = Muscular septum.
m. s. a. = Attachment of septum.
M, = Mantle.
M. C. = Mantle cavity.
M. L. = Limiting membrane.
M_1M. = Muscular mantle.
M. V. = Mantle Veins.
M. W. = Oesophagus wall.
M. ep. = Inner Mantle epithelium.
Matr. = Cartilaginous matrix.
Mem. = Membranous sac.
Mes. = Mesentery.
Mus. = Muscular part of arm.
N_1 = Needham's pouch.
N. = Arterial network in folds of gill filament.
N. A. = Nuchal artery.
N. Circ. = Circular Brachial nerve.
Nuch. M. = Nuchal muscle.
Od. = Oviduct.
od. ap. = Aperture of oviduct.
od. gl. = Oviducal gland.
oes. = Oesophagus.
Oes. g. = Sub-oesophageal ganglion.
o. g. = Oval ganglion.
Olf. cell. = Olfactory cell.
olf. N. = Olfactory nerve.
olf. P. = Olfactory pit.
Opt. G. = Optic ganglion.
Opt. N. = Optic nerve.
Opt. N. f. = Fibres from optic nerve.
opt. N_1 = Nerves to retina.
ov. = Ova.
ov. w. = Wall of ovary.
O.A. = Optic artery.
Oes. A. = Oesophageal artery.
or. = Pyloric aperture.
orb. C. = Orbital cartilage.

orb. V. = Vein to orbital sinus.
p. c. = Polygonal cell.
pad. = Muscular stomach pad.
pch. = Pouch-like dilatation.
pen. = Penis.
ps. ext. = Ext. pseudocorneal memb.
ps. int. = Int. pseudocorneal memb.
ps. mem. = Pseudocorneal membrane.
P. = Pancreas.
P_1 = Terminal suckers of male.
P. C. = Post. communication between mantle cavities.
P. A. = Pancreatic artery.
Pp. = Pupil of eye.
P. M. = Post. membranous wall of brain capsule.
Pall. N. = Pallial nerve.
Pall. V. = Pallial vein.
Ped. G. = Pedal ganglion.
Ph. A. = Pharyngeal artery.
Pig. = Retinal pigment.
Post. Fun. N. = Post. Infundib. nerve.
Post. Sup. oph. = Post. Sup. Ophthalmic nerve.
pr. = Prostate.
r. = Ridge for jaw muscles.
r. b. = Base of radular sac.
r. m. gr. = Right mantle groove.
rad. = Radula.
R. = Rectum.
R. K. = Right Kidney.
R. N. = Retinal nerves.
R. Pall. A. = Right Pallial artery.
R. Pc. ap. = R. reno-pericardial aperture.
R. S. = Radula sac.
R. wall. = Inner wall of oesophagus.
Rec. = Recurrent artery.
Res. = Reservoir.
Ret. = Retina.
Ret. C. = Retinal cell.
Ret. N. = Nucleus of ditto.
S. A. = Salivary artery.
s. d. = Sensory pad.
s. g., s_1 *g.* = Salivary glands.
s. g. d. = Salivary ducts.
sh. = Shell.
s. l. g. = Sub-lingual salivary gland.
sk. = Edge of integument.
s. r. = Sensory ridge.
s. r. o. = Sub-radular organ.
S. = Sucker.
S. a. = Sucker artery.
S. G. = Ganglion supplying suckers.
S. N. = Nerves to sucker.
S. V. = Venous Sinus.
$S_1 V_1$, $S_2 V_2$, $S_3 V_3$. = Divisions of ditto.
S. Vess. = Vein running between successive suckers.
Sept. A. = Septal artery.
Sept. V. = Septal vein.
Sph. = Sphincter of sucker.
St. G. = Stellate ganglion.
scl. = Sclerotic.
Sp. Coe. = Spiral caecum.
St. = Stomach.
Stat. = Statolith.
Str. = Conn. tiss. Stroma.
Sup. V. = Superficial veins of head.
t. = Tongue.
tr. = Secretory trabeculae of Ink gland.
tr. s. = Triangular septum in heart.
T. = Testes.
Tu. = Secretory tubule.
Ur. = Ureter.
Ur. p. = Urinary papilla.
V. = Ventricle.
v. = Trans. valves in spiral caecum.
V. D. = Vas deferens.
V_1, V_{11}. = Secondary Branchial veins.
V_1. = Semilunar valves.
V. app. = Venous appendages.
Visc. A. = Visceral artery.
visc. d. = Visceral dome.
Visc. G. = Visceral ganglia.
Vitr. = Vitreous body.
V. E. = Visceral envelope.
V. Eff. = Vas efferens.
Vasc. N. = Vascular network.
Visc. N. = Visceral nerve.
V. E. A. = Artery to visceral envelope.
V. E. V. = Vein from visceral envelope.
V. S. = Vesicula seminalis.
$V_1 S_1$ = Sac of vitreous fluid.
W. = Web.
W. B. = White body.
W. V. C. = Water vascular canal.
W. V. C. ap. = Opening of water canal into pericardium.

PLATE I.

Fig. 1. Dorsal view of adult female *E. cirrosa*; spirit specimen. × $\frac{5}{8}$.

Fig. 2. Ova of *E. cirrosa*; in formalin. × $\frac{3}{4}$.

Fig. 3. Unhatched embryo of *E. aldrovandi*, right side; in formalin. × 2.

Fig. 4. Older unhatched embryo of *E. aldrovandi*, left side. × 4. (After Korschelt.)

PLATE II.

Fig. 5. Oral view of web of adult *E. cirrosa*; spirit specimen. × $\frac{3}{8}$.

Fig. 6. Mouth and initial sucker of arms, showing internal and external lips. × 1.

Fig. 7. (*a*) Eledone from left side, during inspiration; and (*b*) Eledone from left side, during expiration. × $\frac{3}{8}$.

Fig. 8. *E. aldrovandi*, male; left half of mantle cavity. Young specimen. × 1.

Fig. 9. Funnel, showing muscles; integument cut along line (*sk.*), and funnel turned forward ventrally. × $\frac{1}{3}$.

Fig. 9*a*. Ventral view of anterior part of mantle cavity; to show the locking apparatus. × $\frac{1}{3}$.

Fig. 10. Funnel opened to show funnel organ. × $\frac{1}{2}$.

PLATE III.

Fig. 11. Mantle cavity from ventral side; showing pallial complex and vertical septum. × $\frac{2}{3}$.

Fig. 12. Visceral mass from ventral side, kidneys removed and ink sac dissected away from liver, and turned forward. × $\frac{1}{2}$.

Fig. 13. Postero-dorsal region of mantle, inner surface; viscera removed, and the funnel depressor and lateral muscles partially dissected away, to show the cartilaginous stylets in situ. Diagrammatic. × $\frac{1}{2}$.

Fig. 14. Cephalopedal mass, dissected to show relation of buccal mass to bases of the arms—from ventral surface. × $\frac{3}{1}$.

Fig. 15. Transverse section of mantle in region of cartilaginous stylet. Highly magnified.

Fig. 16. Right stylet (*a*) dorsal view; (*b*) from right side. × $\frac{3}{1}$.

Plate IV.

Fig. 17. Alimentary canal, dissected out from body, to show relations of various parts; crop turned to the right, buccal mass to the left, and liver forwards. × $\frac{1}{2}$.

Fig. 18. Oesophagus with crop, and stomach; slit open to show ridged chitinous lining of all three regions. Muscular walls of stomach turned back from the chitinous lining. × 1.

Fig. 19. T. S. stomach, showing thickened grinding pads, and corresponding thickened cuticle.

Fig. 20. Buccal mass, from right side. × 1.

Fig. 21. Right posterior salivary gland; inner surface.

Fig. 22. Right anterior salivary gland; inner surface.

Fig. 23. Ventral surface of buccal mass, showing sublingual salivary gland. × 1.

Fig. 24. Sagittal section through buccal mass, and anterior portion of oesophagus. × 1.

Fig. 25. Two rows of teeth from radula; much enlarged.

Fig. 26. Sagittal section of ink sac. × 2.

Fig. 27. Jaws, from left side. × 1.

Fig. 28. Spiral caecum; ventral view, showing entrance of hepato-pancreatic duct. × 1.

Fig. 29. Anal ear (enlarged).

Fig. 30. Inner wall of terminal part rectum, showing aperture of ink duct on dorsal papilla. × 2.

PLATE V.

Fig. 33. Transverse section of oesophagus (enlarged).

Fig. 34. Transverse section of tubules of posterior salivary gland.

Fig. 35. Transverse section of tubules of anterior salivary gland.

Fig. 36. Transverse section of secretory tubule of salivary gland, showing secretory cells.

Fig. 37. Kidneys, seen from ventral surface, after removal of visceral envelope. Female. × 1.

Fig. 38. Spiral caecum, opened along columellar edge of spiral, and walls pinned back. The series of transverse valves may be seen, and the internal aperture of the hepato-pancreatic duct. × 1.

Fig. 38*a*. View of viscera, after removing kidney and heart, and turning liver forward—from ventral surface. × $\frac{1}{4}$.

Fig. 39. Ovary, and female genital ducts. The ventral germinal wall has been turned forward anteriorly. × 1.

Fig. 40. Sketch showing relation of pericardial division of coelom to water vascular canal and ureter. Reno-pericardial aperture seen at base of opened ureter. × $\frac{2}{3}$.

Fig. 41. View of portion of germinal wall of ovary, from inner surface, showing attachment of the eggs in racemes. × $\frac{1}{2}$.

Fig. 59. Right gill—ventral view. × 1.

Fig. 60. Portion of gill, from inner surface, showing alternating arrangement of inner and outer leaflets: the central inner leaflet removed. (Enlarged.)

PLATE VI.

Fig. 42. Injection of arterial system, showing the distribution of the main brachial, cephalic, pallial, genital and visceral branches. From ventral surface—partly diagrammatic. × $\frac{2}{3}$.

Fig. 44. Amoeboid colourless blood corpuscles.

Figs. 45 & 46. Heart bisected in median antero-posterior plane. Fig. 45 shows dorsal portion from inner surface, and entrance of anterior and genital aortae; also triangular septum. Fig. 46 shows ventral portion from inner surface, with openings of auricles and abdominal aorta. × 1.

Fig. 47. Heart bisected in median dorso-ventral plane, and viewed from cut surface. (*a*) Left half of heart—inner surface, showing triangular septum. (*b*) Right half. × 1.

Fig. 48. Semi-lunar auriculo-ventricular valves, looked at from ventricle. × 1.

Fig. 49. Diagram showing relation of inferior intestinal arteries, and abdominal aorta, to artery of the ink sac. × 1.

Fig. 50. Buccal mass from left side, showing distribution of left pharyngeal artery and branches. × 1.

Fig. 51. Sketch showing distribution of left branchial artery, and its oviducal branch. × $\frac{2}{3}$.

Fig. 63*a*. Sketch showing polygonal cells of branchial gland, and the intercellular blood sinuses.

Fig. 65. Epithelial and olfactory cells lining the olfactory pit. (After Zernoff.)

Fig. 66*a*. Portion of cartilage, showing branching and anastomosing processes of cartilage cells.

PLATE VII.

Fig. 52. Figure of venous system, from ventral surface, partly diagrammatic, showing principal cephalic, and pallial veins, and three venae cavae. × $\frac{2}{3}$.

Fig. 53. Large perivisceral blood sinus and its connection with the lateral and anterior venae cavae. Ventral surface. × $\frac{1}{2}$. Partly diagrammatic.

Fig. 54. Two adjacent arms, showing venous vessels and common interbrachial vein. × $\frac{1}{3}$.

Fig. 55. Left branchial heart, showing the branchial appendage or pericardial gland. From ventral surface. × 1.

Fig. 56. Distal portion of lateral vena cava, showing two semi-lunar valves at entrance to branchial heart, and also apertures leading into venous appendages, and into the network of vessels occurring in the spongy wall of the branchial heart. × 1.

Fig. 57. Mantle cut down ventral median line, and opened out flat. The left half is seen from the dorsal surface, after removing the skin. *M. V.* and *M. V.*$_1$ represent the two main pallial veins. × $\frac{1}{4}$.

Fig. 58. Portion of arm, showing relation of main veins to the network which drains the arm. × $\frac{2}{3}$.

PLATE VIII.

Fig. 31. Ventral view of ink sac, after removal of epithelium covering visceral sac, showing visceral nerves, and nerve artery and vein of ink sac. × $\frac{3}{4}$.

Fig. 32. Ventral view of ink sac, showing veins and arteries injected. The visceral and iridescent envelopes cut open and turned back. × 1.

Fig. 43. Heart from ventral surface, showing paired coronary veins. × 1.

Fig. 61. Gill leaflet, showing network of arteries flowing into the main axial vessel which leads into the efferent artery. × 1.

Fig. 62. Portion of gill filament from external surface, showing terminations of venous vessels of the second order. × 1.

Fig. 63. Portion of gill, from inner surface, showing main arteries and veins injected—second inner filament cut away. Much enlarged.

Fig. 67. Right statocyst, from ventral surface. × 3.

Fig. 67*a*. Statolith, from free surface. Much enlarged.

Fig. 68. Auditory capsules opened to show the statocyst attached to capsule by vascular network. × 1.

Fig. 72. Buccal bulb from left side. The suboesophageal ganglion and its branches (*a*—*g*), and the buccal nerve are shown. × 1.

Fig. 79. Longitudinal median vertical section of arm, showing brachial artery and nerve, nerve ganglia corresponding to the suckers, and network of fine arteries and veins which surrounds them. × 1.

Fig. 80. Dissection of dorsal surface of head, showing the circular nerve which unites the brachial nerves, at the bases of the arms. × $\frac{1}{2}$.

Plate IX.

Fig. 69. Ventral dissection of nervous system, partly diagrammatic. Funnel cut open and turned aside, muscular septum removed; the branches from ganglia on visceral nerves are shown only on the right side. × $\frac{2}{3}$.

Fig. 70. Central nervous system, from left side. Slightly enlarged.

Fig. 71. Left optic ganglion and nerve from dorsal surface. × 1.

Fig. 73. Dissection of gastric ganglion and its branches (*a*—*h*). The alimentary canal is seen from the ventral surface.

Fig. 74. Dissection of the superior ophthalmic nerves, and the olfactory nerves from the dorsal surface. The skin and superficial muscles have been dissected away and turned back, showing the muscular coat of the eye, the bases of the arms, and the muscles covering the cranial cartilage. × $\frac{2}{3}$.

Fig. 75. Lateral view of right eye, after dissecting away the superficial muscles and skin. Shows anterior superior and inferior ophthalmic nerves. × $\frac{1}{2}$.

Fig. 76. Buccal mass and central nervous system, dorsal view. The course of the labial (*a*—*d*) and buccal nerves may be seen. × 1.

Fig. 77. Median vertical longitudinal section of arm, showing the ganglion and group of nerves, which supply each sucker.

Fig. 67*b*. Diagrammatic longitudinal section through two ova, showing their mode of attachment to the germinal wall, and also numerous folds of the follicle, which nourishes the developing ovum. In left hand corner is a diagram of an egg in transverse section, showing the infolded follicular membrane.

PLATE X.

Fig. 78. Diagram of median vertical section of eye. The whole optic ganglion is drawn in order to show the relation of the retinal nerves to the retina and ganglion. The small figure on the left shows the outer segment of the lens, from the surface which rests on the cornea. × 2.

Fig. 81. Diagram of the parasite *Dicyema mulleri*, found in the kidney fluid of *Eledone cirrosa*. Much enlarged.

Fig. 82. Anterior region of visceral envelope, from inner surface, showing posterior membranous wall of brain case, and various nerves. × $\frac{2}{3}$.

Fig. 83. Eye from external surface, showing lid and pseudocorneal membrane. × 1.

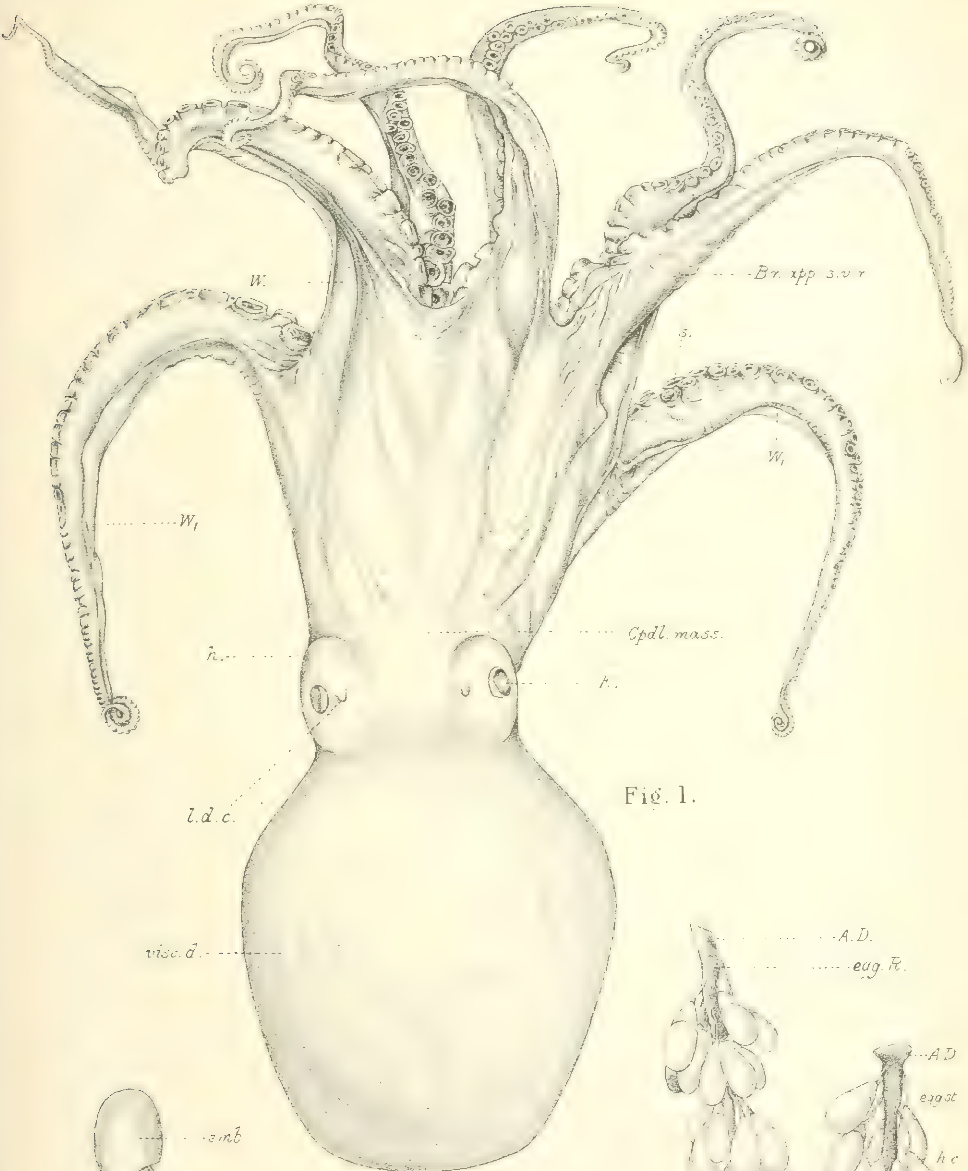
Fig. 84. Median dorso-ventral section through eyelid and pseudocorneal membrane. × 1.

Fig. 85. (*a*) Cranial and orbital cartilages, from dorsal surface. (*b*) The same, ventral view. × $\frac{1}{2}$.

Fig. 86. Vertical section through portion of the retina.

Fig. 64. Dorso-ventral section through olfactory pit, much enlarged, showing the folded sensory wall.

Fig. 66. Right olfactory pit; mantle turned back. × 1.



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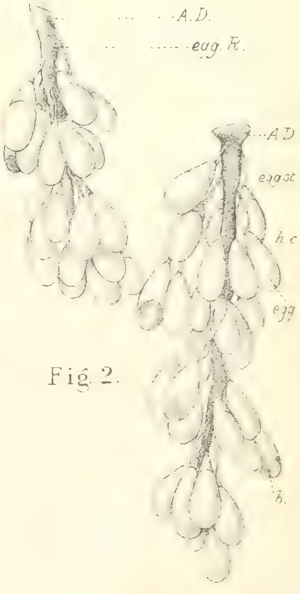

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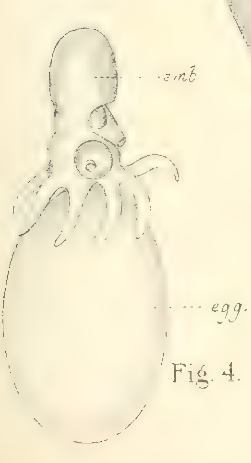

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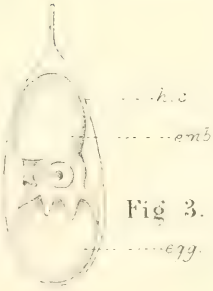

Fig 3.

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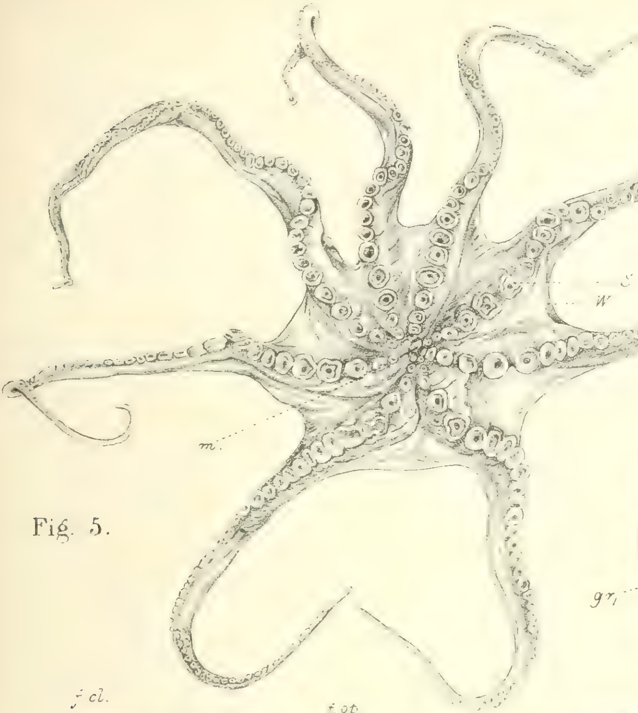

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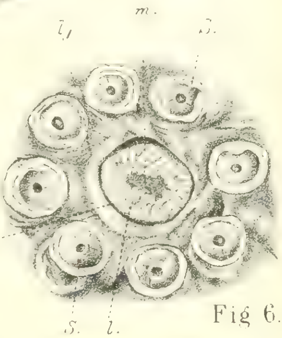

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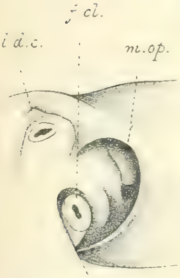

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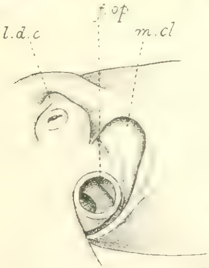

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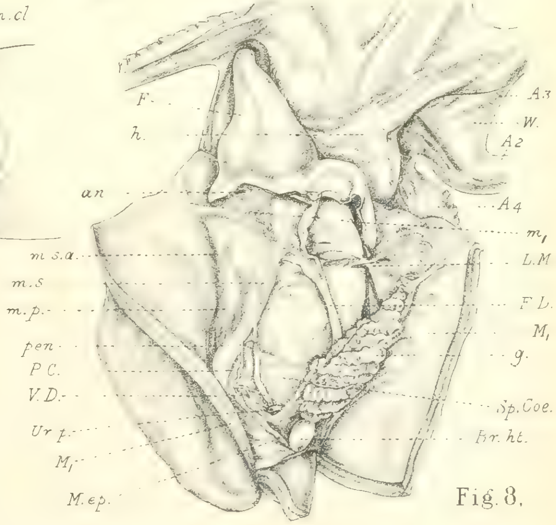

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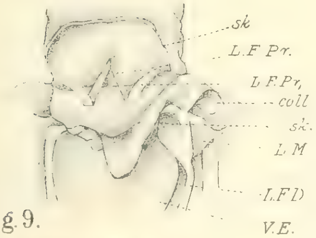

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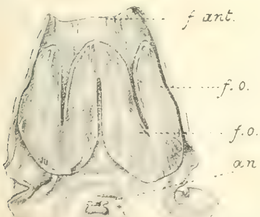

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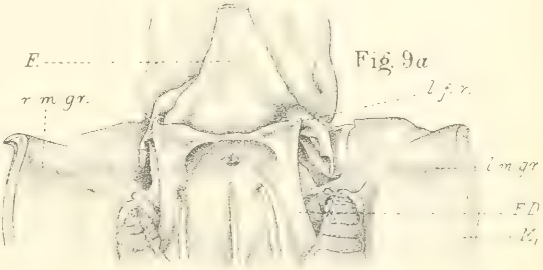

Fig. 9a

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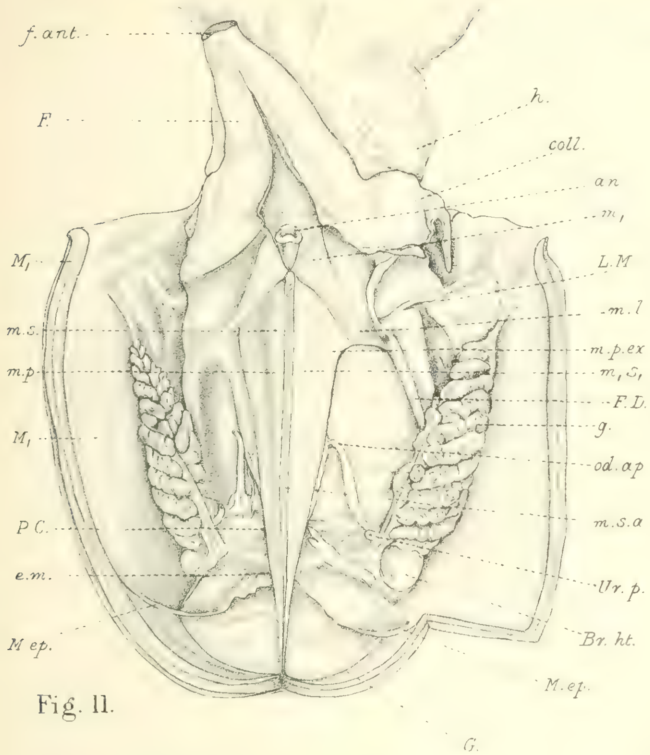

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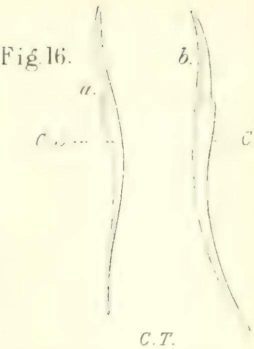

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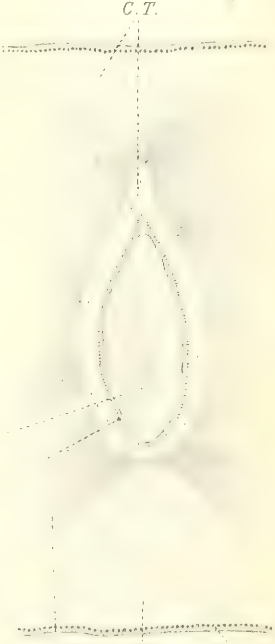

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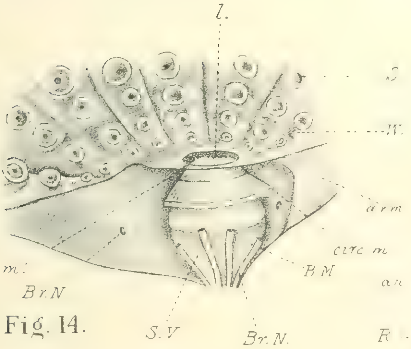

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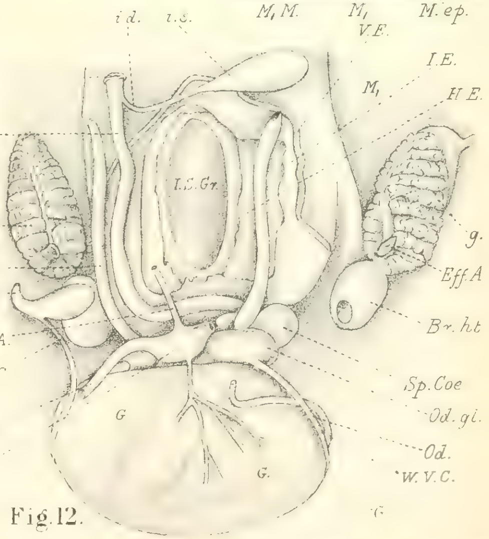

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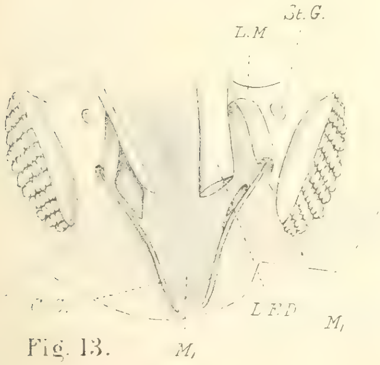

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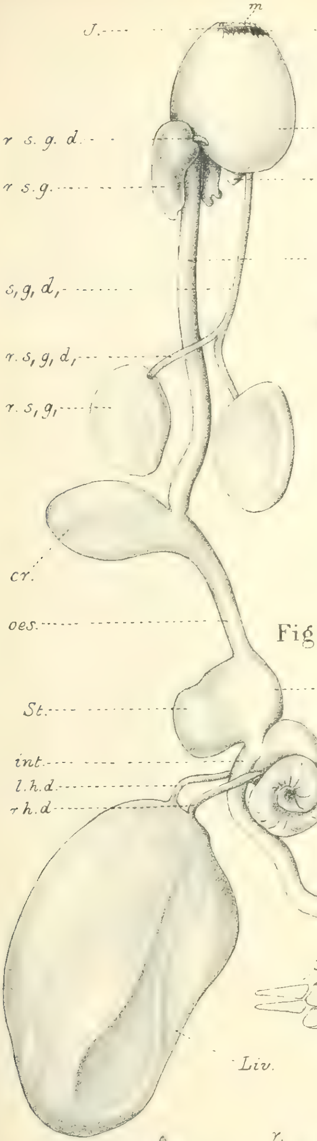

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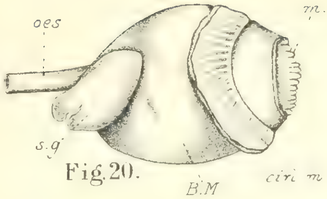

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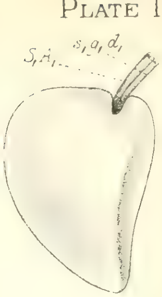

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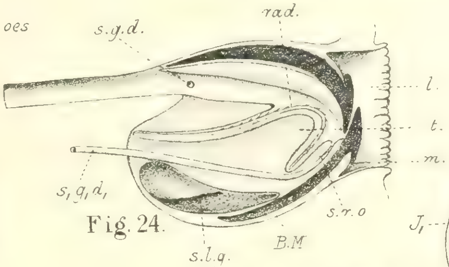

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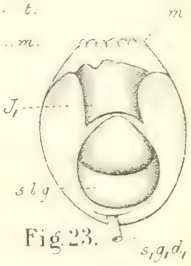
Fig. 22



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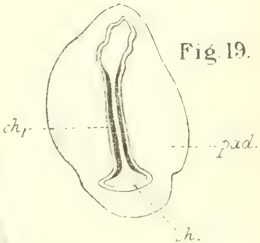

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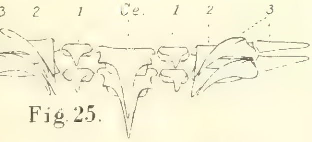

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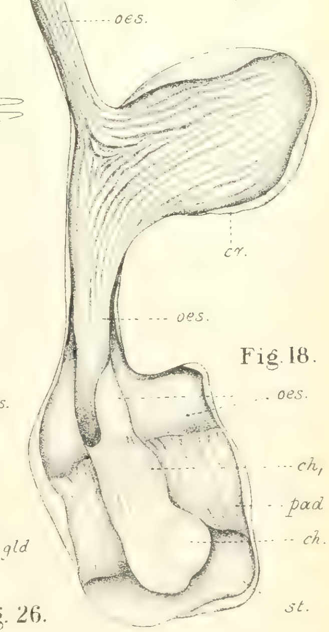

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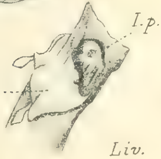

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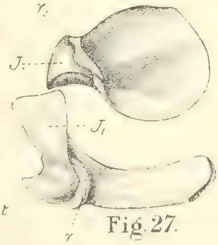

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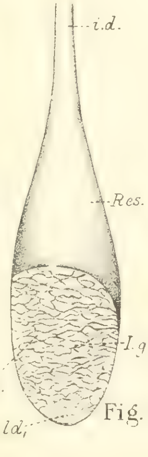

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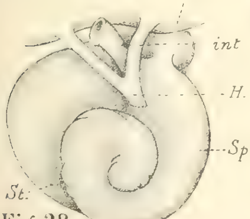

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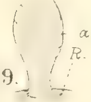

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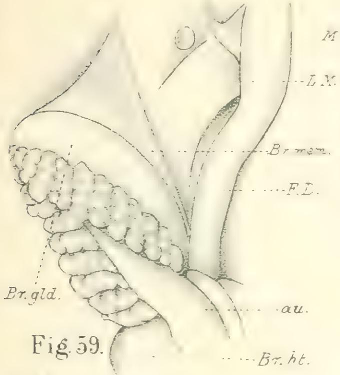

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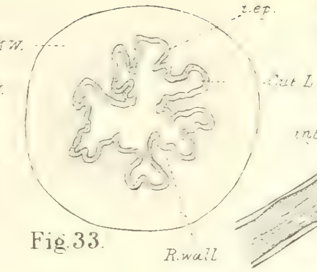

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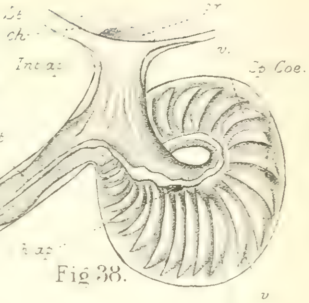

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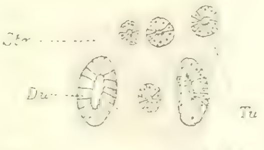

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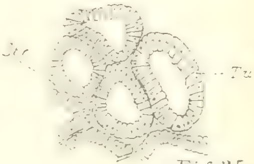

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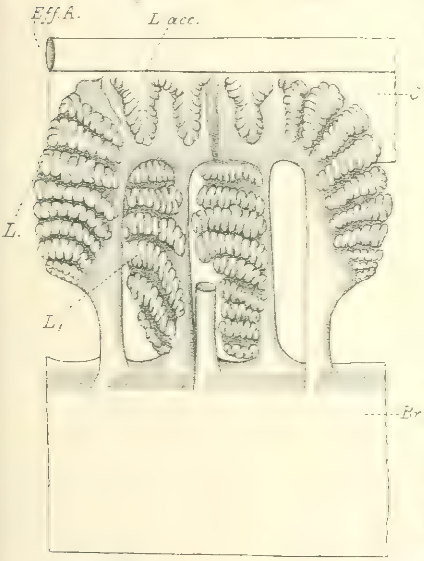

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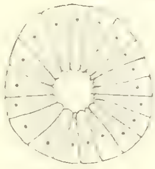

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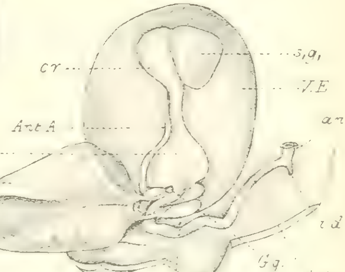

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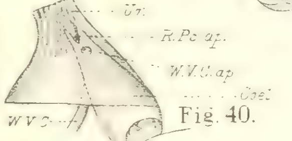

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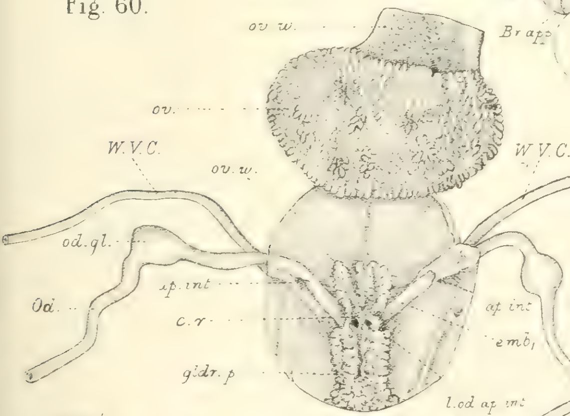

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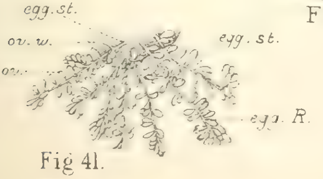

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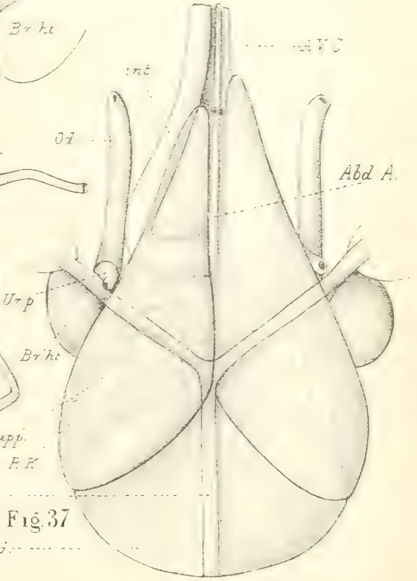

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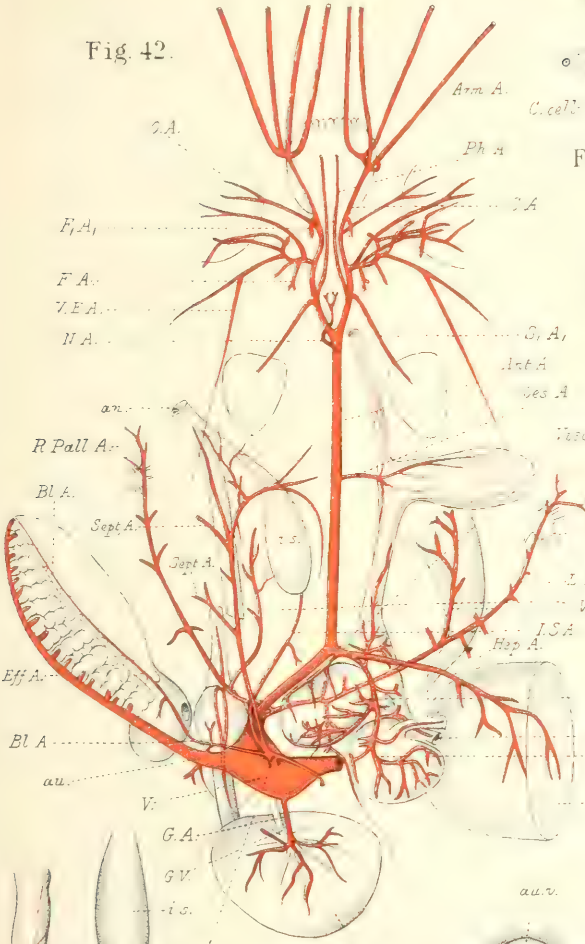

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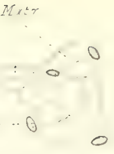

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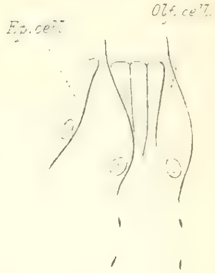

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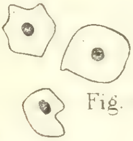

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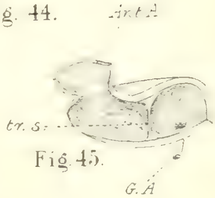

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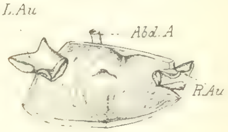

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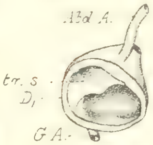

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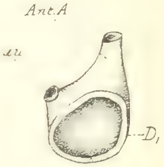

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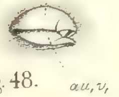

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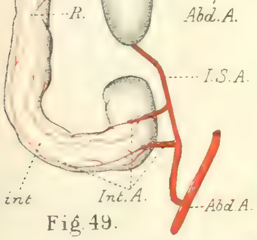

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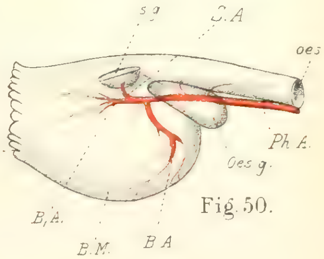

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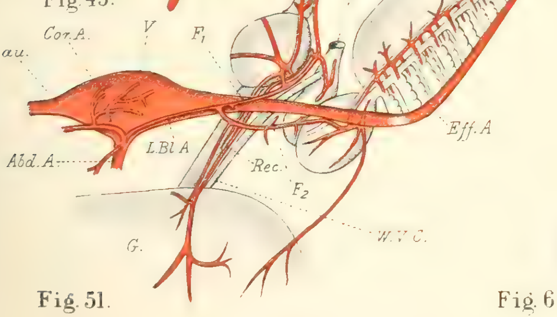

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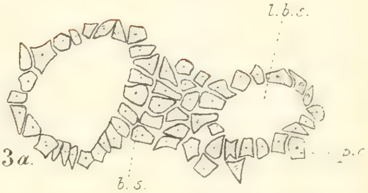

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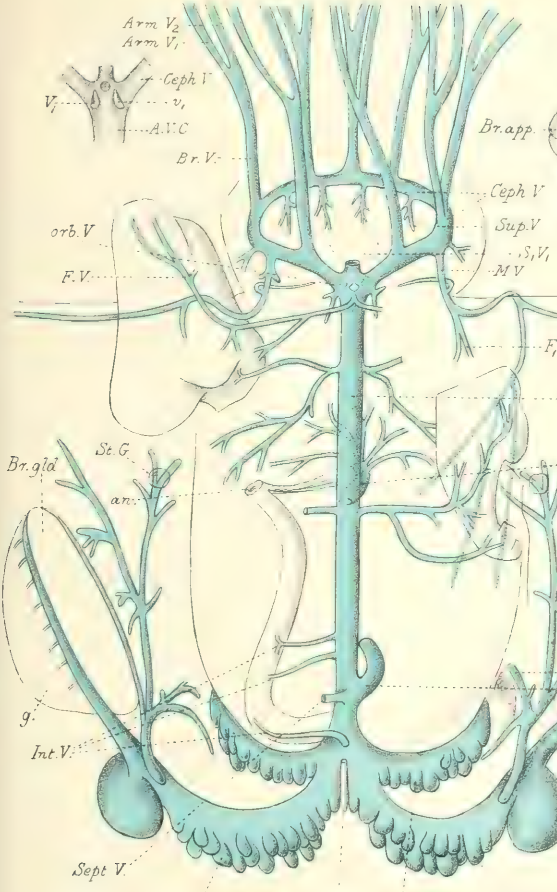

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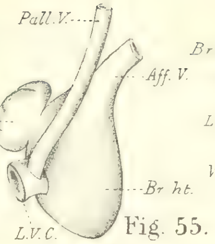

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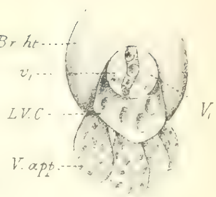

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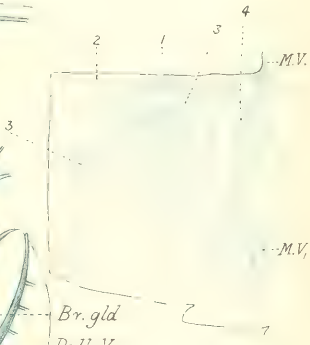

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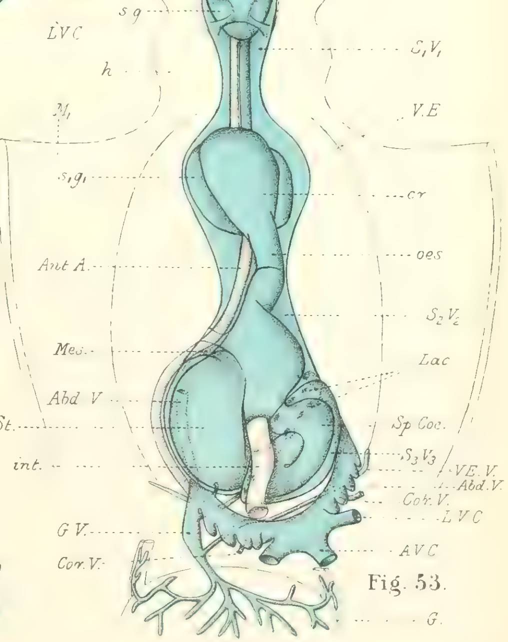
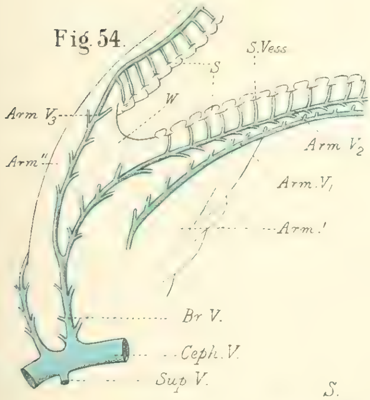


Fig. 53.



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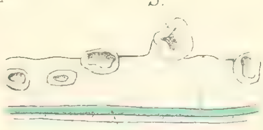

Fig. 58.

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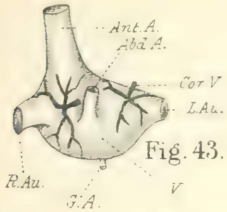


Fig. 43.

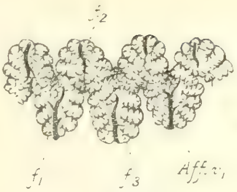


Fig. 62.

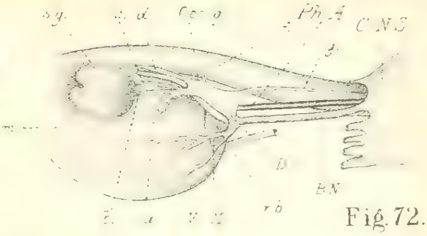


Fig. 72.

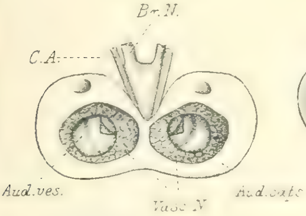


Fig. 68.

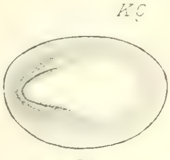


Fig. 67a.

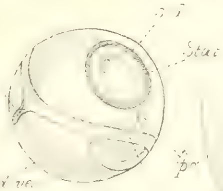


Fig. 67.

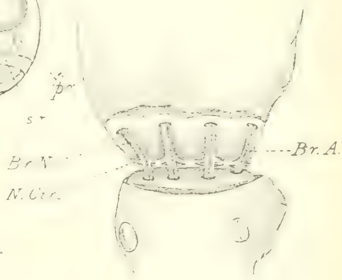


Fig. 80.

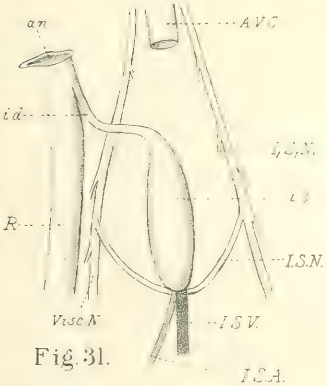


Fig. 31.

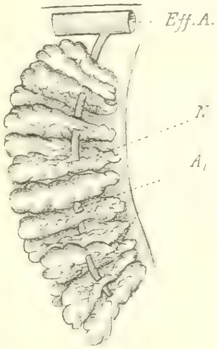


Fig. 61.

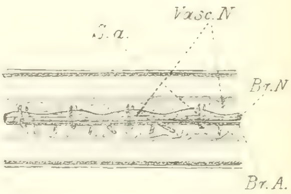
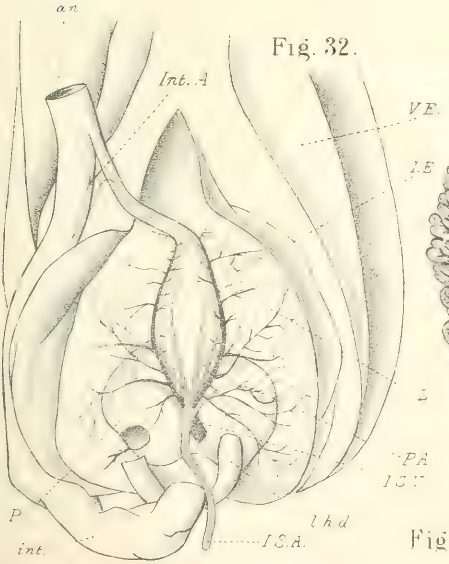


Fig. 79.



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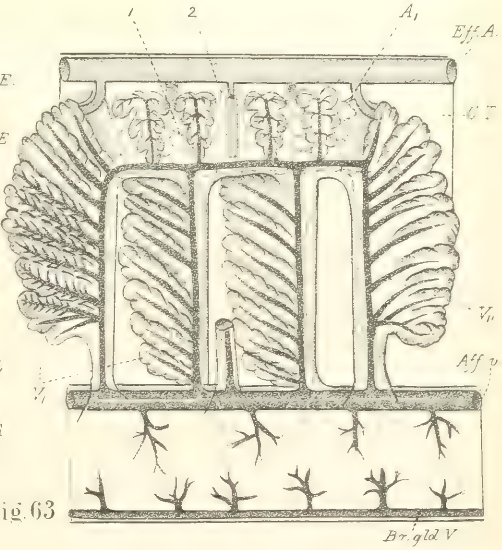

Fig. 63

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Fig. 69.

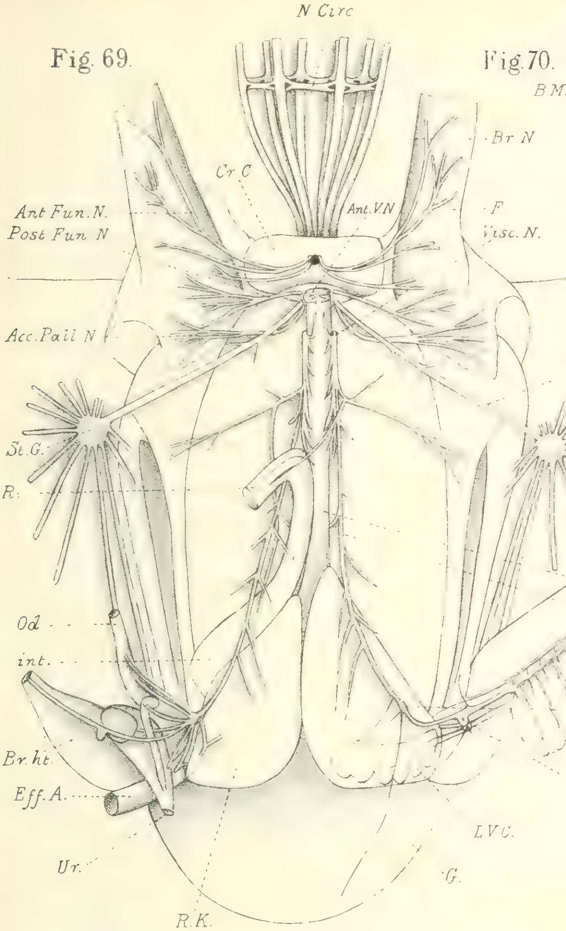
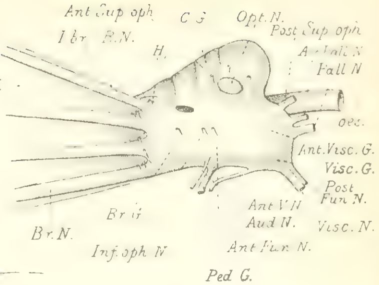


Fig. 70.



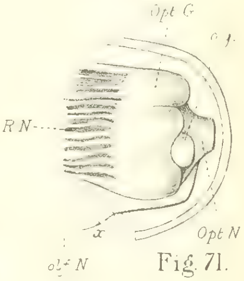


Fig. 71.

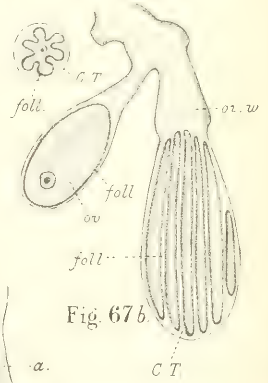


Fig. 67 b.

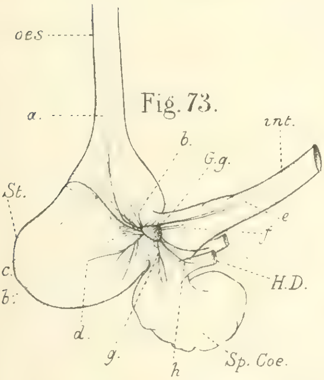
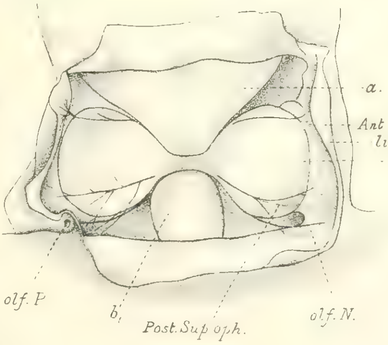


Fig. 73.

Fig. 74.



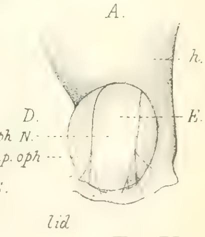
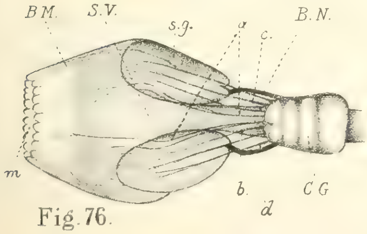


Fig. 75.



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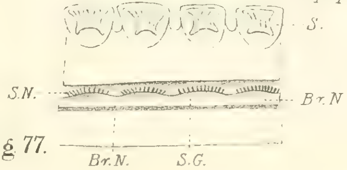

Fig. 77.

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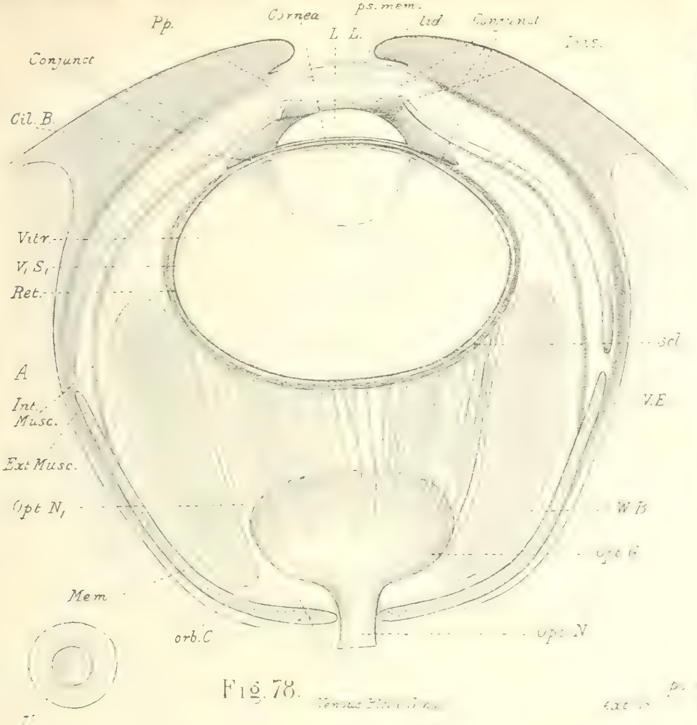

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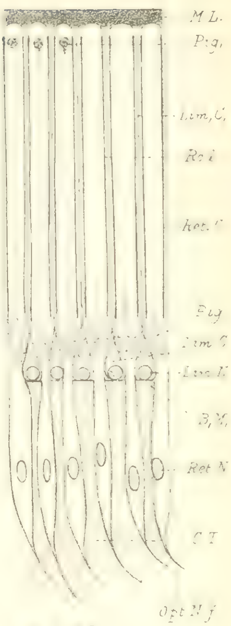

Fig 86.

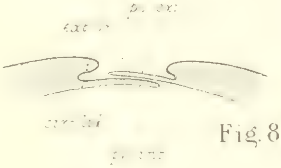

Fig. 84.

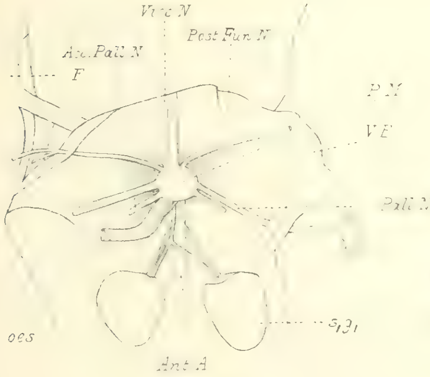

Fig. 82.

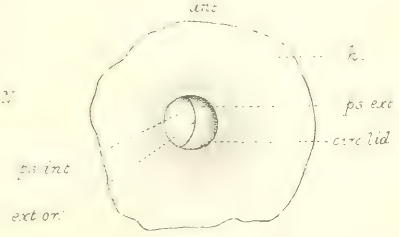

Fig. 83.

Fig. 81.

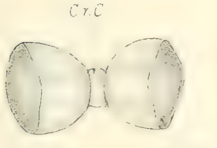

Fig. 85 *a*.

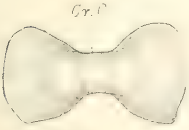

Fig. 85 *b*.

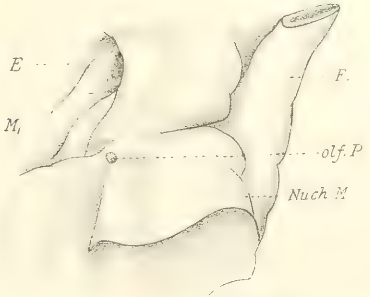

Fig. 66.

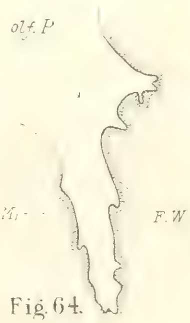

Fig. 64.

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L.M.B.C. MEMOIRS.

No. XIX.

POLYCHAET LARVAE OF PORT ERIN.

BY
F. H. GRAVELY, M.Sc.,
Junior Demonstrator of Zoology in the Victoria University of Manchester.

INTRODUCTION.

Previous Work upon Polychaet Larvae of the L.M.B.C. District.

There appear to be only two papers which touch upon this subject. Mr. Chadwick (1899) has recorded the tubicolous post-larval stage of *Pectinaria* and also the larvae of several other Polychaets; some of the latter are figured, but none identified. Mr. Hornell's account of the L.M.B.C. Polychaeta (1891) includes a "Note on the Embryology of *Arenicola* and *Scoloplos*." It would appear, however, from the foot-note to p. 314 of Vol. II. of the Cambridge Natural History that the egg-capsules and larvae here referred to as those of *Arenicola* are now known to belong to a Phyllodocid—*Phyllodoce maculata* according to Hornell himself: *Eulalia viridis* according to some others. Hornell's figures of these larvae strongly suggest that the tuft of apical cilia that he describes represents in reality the "hook" of cilia characteristic of Phyllodocid larvae; and they closely resemble McIntosh's figures of the larvae of *Phyllodoce maculata* (McIntosh: 1869).

MATERIAL AND METHODS.

The larvae which form the subject of the present paper may all be obtained at Port Erin during July: but the observations recorded were commenced in 1907 about the middle of June, and in 1908 were continued during the early part of August.

All the species have been obtained in the bay, for the most part just inside the breakwater or further out towards the cliffs opposite the Biological Station. Townettings were also taken one evening between Aldrick Bay and the Calf Island, but the catch contained just the same Polychaet larvae as those from within the bay.

A simple bolting-silk tow-net (mesh 94), usually sunk some distance (probably about 3 fathoms) below the surface, was used to obtain the plankton which was either fixed in the boat or taken up to the laboratory and examined immediately in the living condition: none of the larvae were reared in the aquarium. Notes and rough sketches of the living larvae were made in the laboratory, and from these and stained microscopical preparations the following descriptions and figures have been drawn. In some instances use has also been made of sections to determine doubtful points.

Whilst examining the living larvae I endeavoured to obtain measurements of their cilia. This was rendered extremely difficult both by their great activity and their frequently oblique position or curvature. The measurements given must therefore be regarded as approximate only. In the case of cilia projecting obliquely from the body, I have endeavoured to ascertain the length of the cilia and not the perpendicular distance of their distal ends from the body, a measurement that may easily be taken to represent their actual length as long as they are actively in motion. Though only approximate, these figures will, I think, convey a better idea of the relative lengths of various cilia than could be obtained from the constant use of such vague comparative terms as "long," "medium," and "short."

This paper can only claim to give a preliminary account of the larvae it describes; as, however, many of these larvae have not been described before, and as no systematic account of British Polychaet larvae has yet been attempted, even for such a limited area and part of the year as Port Erin Bay during the month of July, it seems advisable to publish it in its present form, and to leave the obvious gaps in some of the accounts to be filled in as opportunity presents itself. I have endeavoured by references to previous work on the subject to indicate briefly the nature and extent of the variability of larvae within each of the families dealt with, and their complete life-histories as far as they are at present known.

I should like to express my thanks to Prof. Hickson for nominating me to the Manchester University table in the laboratory at Port Erin during the times I was collecting the material described below; also to Prof. Herdman for very kindly supplying me with samples of the plankton he collected from his steam-yacht "Ladybird" in the large "shear-net," from which it was hoped —unfortunately in vain—that there might be obtained later stages of Polychaet larvae than those caught in the ordinary small tow-nets; and finally to Mr. Chadwick for many valuable suggestions, and ready help in many ways.

DESCRIPTIONS OF THE LARVAE.

I.—NEREIDIFORMIA.

SYLLIDÆ.

Three species of undoubted Syllid larvae have been found. As these closely resemble each other in general features, they may be treated together and distinguished when necessary as Syllids *A*, *B*, and *C* respectively. It is impossible to determine even the genus of any one of them.

Metatrochophore.*—Two specimens (one of sp. *A*, the other of sp. *C*) are in the second metatrochophore stage, but I have not had the opportunity of examining them alive. No earlier stage than this has been seen. These two larvae are pear-shaped (about 350μ long by 250μ maximum diameter), with the prototroch (or "preoral" ciliated band) in the position of greatest breadth. There is a narrow ciliated tract round the mouth; and the akrotroch and one pair at least of the eyespots seen in living specimens of the Nectochaeta of species *A* are probably also present, in that species at any rate.†

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* The technical terms commonly adopted in describing the different stages, larval organs, etc., found during the development of Annelids are those defined by Häcker (1897, pp. 74-76). Most of these terms require no alteration to render them suitable for English use: the term "Zwischenparatroch" has, however, been replaced by "Interparatroch," and the term "Endparatroch" by the less awkward and equally well known term "Telotroch." In addition to the terms defined by Häcker I have found it convenient to distinguish, with Claparède (1863, p. 87), between amphitrochal, nototrochal and gastrotrochal segmental ciliated bands according to whether they completely encircle the body or are confined to the dorsal or to the ventral surface. In addition I have used the term "Neurotroch" to designate the longitudinal ciliated tract frequently found between the mouth and anus. Definitions of all these terms will be found in my "Studies on Polychaet Larvae" (Gravely, 1909, pp. 597-600).

† See footnote to Nectochaeta stage below.

Only the five primary segments are present, but of these the last three bear appendages, even in the younger specimen (sp. *C*): whilst in the other (sp. *A*: Pl. I., fig. 1) the first (peristomial) segment bears on each side a lobe representing its dorsal cirrus; the second bears two similar lobes, representing respectively the single ramus of the parapodium, and its dorsal cirrus; the third bears a similar rudimentary dorsal cirrus, but a distinct chaetigerous parapodial ramus; the fourth a still longer parapodium; and the fifth a parapodium somewhat shorter than that of the fourth segment.

Nectochaeta.—This stage may be said to begin in the Syllidae with the development of the parapodia of the anterior secondary segments. During this development the ventral peristomial cirri appear, together with the ventral cirri of the anterior chaetigerous segments, the cephalic tentacles, and palps; whilst the dorsal peristomial cirri increase in length.

The prototroch, in species *A* at least, is still used for swimming, whilst the parapodia are used for crawling whenever swimming is impeded. The setae are very long, and can be almost entirely withdrawn into the parapodium. The prototroch is complete, and consists of two rows of cilia* (Pl. I., fig. 1); those of the anterior row are 70μ in length, those of the posterior 50μ. The mouth is lined with shorter cilia, and an akrotroch—a tuft or row of cilia between the prototroch and the apical plate—is present in the form of a median ventral tuft of cilia 20μ in length, situated just in front of the prototroch in the hollow between the umbrella and the apical region of the

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* I have since been able to distinguish in a Syllid Metatrochophore (*? Syllid B*) a row of very short cilia anterior to these, as in *Polynoë*. These two rows, therefore, correspond to the posterior two rows of equal cilia in *Polynoë*, which they further resemble in that one row is held directed forwards and the other backwards. This larva bore three pairs of eyespots and a tuft of akrotrochal cilia 20μ long.

larva. No cilia have been detected upon any other segment.

The larva is transparent and almost colourless except for material in the gut, two pairs of opaque, dark brown or black eyespots on the dorsal surface of the prostomium, and traces of opaque pigment on the prostomium and on the posterior surface of the anal segment.

Syllid A (Pl. I., figs. 1 and 2).—This, the most plentiful, is characterised by the setae shown in fig. 2: one of the simple (anterior) and four or five of the compound setae occur in each tuft. Anal styles are present in every specimen, being indicated even in the Metatrochophore shown in Pl. I., fig. 1.

In the oldest specimen obtained there are seven chaetigerous segments, the parapodia of the first of these still being shorter than those of the segment immediately behind them: both dorsal and ventral cirri are present on every parapodium, the dorsal at its base, the ventral about half way along it; the dorsal cirrus is larger than the ventral. The two pairs of peristomial cirri are both present, the dorsal being about 100μ long, and the ventral rather less than half that length; the dorsal pair are very slender, and transparent distally. There is no trace of cephalic tentacles or palps. In one Nectochaeta of this species a stout aciculum, slightly curved distally, is embedded in the tissues at the base of the peristomial cirri.

Syllid B (Pl. I., fig. 3).—This species is characterised by the presence, in each tuft of setae, of two simple capillary setae, one shorter and more slender than the other, and several compound ones, the latter each with a long filamentous distal segment (Pl. I., fig. 3).

The two youngest larvae seen both possess five pairs of parapodia, and are 500μ in length by 150μ in breadth. Though possessing fewer segments than the oldest specimen of *Syllid A* described above, the tentacles and dorsal cirri are much more fully developed; all three cephalic tentacles are present, though very short—the median one especially so. A pair of broad, but slightly developed, lobes, situated at the sides of the head immediately in front of the prototroch, represent the developing palps.

The dorsal peristomial cirri are longer than the ventral, but shorter than the dorsal cirri of the second (first chaetigerous) segment, which likewise exceed in length those of the succeeding segments. As in *Syllid A*, however, the rami of the parapodia of the second segment are shorter than those of the third. The parapodia of the fourth and succeeding segments only, each bear, close to their distal extremities, a short ventral cirrus. Anal styles are not present, but may have been shed at death.

The only other larva of this species that has been seen is much longer in proportion to its breadth, on account of the presence of two additional segments which have developed unaccompanied by any increase in breadth. The parapodia, with their dorsal cirri, are shorter than in the younger specimens, probably through contraction; their lengths relative to each other, however, remain the same, with the parapodia of the first chaetigerous segment shorter than those of the second. The ventral cirri are slightly more developed than in the younger larvae, and are still absent from the first two pairs of chaetigerous appendages. Anal styles are present and of considerable size.

Syllid C (Pl. I., fig. 4). Only a single specimen has been found, and that in an earlier stage than any of the other Syllid larvae. It is characterised by the rounded end of the proximal segment of its compound setae (Pl. I., fig. 4, B), this being pointed in the other two species; by the form of the distal segment of these setae (Pl. I., fig. 4, B); and by the form of the simple setae (Pl. I., fig. 4, A), which occur one in each bunch.

Three pairs of parapodia only are present, the first two segments being as yet in no way recognisable externally. These three pairs of parapodia (belonging to segments 3-5) scarcely project at all as lobes from the sides of the body, but each bears a tuft of well-developed setae.

Malaquin (1893, pp. 389-426) has fully described and figured the development of *Autolytus edwardsi* and *Eusyllis monilicornis*; and in less detail, that of *Syllis hyalina*, *Grubea*, *Exogone*, and a few other forms. His larvae are all of the same general type as the three described above, but differ from them in important specific characters. He finds that those larvae in which the early developmental stages are most slowly passed through are polytrochal, the cilia appearing very early and, excepting those of the prototroch, being confined to the dorsal surface and disappearing from before backwards. In those forms, however, in which the early stages are abbreviated the cilia do not appear until a later period, and then only on the head and posterior segments. Finally, in extreme cases, the cilia are not developed at all. Some larvae of this last type—*Exogone gemmifera*, *Sphaerosyllis pirifer*, *Syllides pulliger* (?), and *Grubea limbata* (?)—are carefully described by Viguier (1884); these larvae also conform to the same general type as the other Syllid larvae. Of this same form also are the four species of atrochal larvae belonging to the tribe Exogoneae and the polytrochal Odontosyllis larva described and figured by De Saint-Joseph (1886: Pl. X., figs. 76, 78-80, 86-91; and Pl. VIII., fig. 40). A slightly different form of larva has, however, been described by Korschelt (1893: pp. 279-285, Pl. XIII., figs. 16-29) under the name of "*Harpochaeta cingulata*" and referred to the Syllidae. This larva is polytrochal, its appendages arise much later than appears to be usual in the Syllidae, and it is characterised in the later stages by the presence of a pair of stout sickle-shaped bristles on every segment after the fourth, and by the deeply pigmented anal segment.

(?) **Syllid** (Pl. I., fig. 5).—Only the first metatrochophore stage of this larva has been seen, and this gives no clue to its systematic position; it appears, however, to be of the same species as a larva described by Häcker (1896: pp. 82-84; Pl. III., figs. 6-7) and considered by him to be probably a Syllid. Only two specimens have been seen, and these were not examined alive. The larva is nearly four times as long as it is broad, and bears four equally developed ciliated bands, one near each end and the other two a quarter and half way respectively from the anterior to the posterior band (Pl. I., fig. 5). The maximum breadth of the larva occurs between the second and third bands, there being no umbrella. Häcker figures a pair of eyespots in front of the anterior ciliated band in his larva. No setae are present.

Häcker (1896, pp. 82-84: Pl. III., figs. 6-7) describes and figures this and a later metatrochophore stage of this or a very similar larva. The latter has about fifteen segments, each containing a stout sickle-shaped bristle, but bearing no projecting parapodia. The eyes (still a single pair) are larger than before, and there is an extremely large and conspicuous patch of pigment on the anal segment. He considers that this larva comes very near to "*Harpochaeta cingulata*," described by Korschelt

(1893: p. 279; Pl. XIII., figs. 16-29), on account of its general form, its polytrochy, the position of its eyespots, the condition of its mid-gut, its sickle-shaped bristles, and the pigmentation of its anal segment. Of these characters the polytrochal condition of this larva appears to me to be a secondary specialisation, quite distinct from the simple polytrochal condition of "*Harpochaeta*"; nor do any of the characters seem very conclusive. Our form is certainly very unlike any other known Syllid larva, such as De Saint-Joseph's, as Häcker himself points out; and although "*Harpochaeta*" may to some slight extent help to bridge the gap, the evidence that this larva is a Syllid appears to me to be insufficient.

POLYNOIDÆ. (Pl. I., figs. 15-20.)

There appear to be several species, belonging to one or more genera of the Polynoidae, occurring as larvae at Port Erin during July. I have not yet been able to go fully into the differences between them, but the following account refers especially to the commonest of these, and with but slight modifications is true of all.

Trochophore.—The Trochophore after fixation is usually somewhat longer than it is broad, having a length of 300μ and a breadth of 250μ: but during life it is of a more nearly spherical shape (Pl. I., fig. 15). The commonest form appears to be of a deep violet colour, on account of the pigmentation of the walls of the stomach.

The prototroch consists of three rows of cilia (Pl. I., fig. 15, 15a), which are probably carried by three corresponding rows of cells. The cilia of the most anterior row are 15μ long, and sections show that this row is situated slightly in front of the other two, which arise close together, the cilia of one being directed forwards and those of the other backwards; the cilia of both these rows are 80μ long.

The apical pole of the larva bears a circlet of 40μ cilia, and close to this is situated dorsally a slight thickening of the body-wall (Pl. I., fig. 15, *T. med.*), the rudiment of the median cephalic tentacle. Between the apical cilia and the prototroch an akrotroch (Pl. I., figs. 15, 15a, *Akr.*) extends about half way across the ventral surface: of these cilia those near the middle line are longer (40μ) than the rest (20μ).

A little in front of and dorsal to the ends of the akrotroch is situated a somewhat crescentic eyespot of an extremely dark brown colour. The mouth opens below a very prominent upper-lip, along which the prototroch extends (Pl. I., figs. 15, 15a). On each side of the mouth there extend downwards and forwards from the posterior border of the prototroch a row of exceptionally long (150μ) cilia, which are always held straight and motionless, with their distal ends converging (Pl. I., fig. 15, *C*); these cilia appear to be absent in some species. Behind the prototroch a patch of 30μ cilia extends backwards round the mouth over quite an extensive portion of the ventral surface (Pl. I., fig. 15a, *C. or.*). A neurotroch (cilia 4μ long) extends forwards from the anus, but does not quite reach this oral ciliated area.

The deeply-staining region of the prostomium (rudiment of the supra-oesophageal ganglion—see Häcker, 1895, pp. 258-9) is large (Pl. I., fig. 15, *Ant.*). Another pair of deeply-staining masses of tissue, meeting in the middle line, extend on the ventral surface from the prototroch to the posterior end of the body, and mark the region of the subsequent development of parapodia and ventral nerve cord. The dorsal portion of the body-wall is thin and transparent.

The oesophagus is very narrow, and already bears a pair of little diverticula which ultimately form the thick walls of the pharynx. The stomach—which often contains the skeletal parts of unicellular organisms—is provided with a large dorsal lobe or caecum (Pl. I., fig. 15, *Caec.*), and its walls are thickly packed with minute opaque granules which probably give them their deep violet colour.

Metatrochophore.—The first metatrochophore stage closely resembles the trochophore, but is distinguished by the segmentation of the deeply-staining tissues of the ventral surface behind the prototroch. The larva is, moreover, larger and two pairs of more rounded eyes appear, one slightly anterior and the other slightly dorsal to the original crescentic pair. A very short row of 150μ cilia can often be detected along the dorsal side of each of the crescentic eyes in this and later stages; I have been unable to find these in the specimens of the trochophore stage.

The Metatrochophore increases in size and becomes more pointed at the posterior end (Pl. I., fig. 16) as it passes into its second phase. The peristomial cirri appear close together immediately behind the prototroch; a pair of anal styles appear at the posterior end; and between these, set very close together, the parapodia of seven chaetigerous segments develop. Each of these shows from the very first recognisable rudiments of all parts of the fully formed appendage except the dorsal tuft of setae; whilst the elytra of segments 2, 4, 5, 7 (and later 9, 11, 13, etc.) are more disc-like than the dorsal cirri of the other segments even at this early stage (Pl. I., fig. 16, *El.*). The pair of diverticula of the oesophagus have become much larger, and their walls much thicker than in the Trochophore.

By the end of the metatrochophore stage (Pl. I., fig. 17) the appendages of the first eight segments have all assumed their final form. The parapodia project from the body-wall to a distance of 100μ (exclusive of the setae), and the dorsal tuft of setae has made its appearance; the elytra are about 150μ in diameter. The parapodia of the ninth segment are developing: it is hard to determine whether this is a belated primary or precocious secondary segment, for although it appears only after the parapodia of the eight preceding segments have reached an advanced stage, yet it develops so rapidly that it soon reaches the same condition, and the parapodia of these nine segments alone function throughout the nectochaeta stage, towards the end only of which do any further segments begin to appear.

Shortly before the end of the metatrochophore stage the neurotroch disappears. In preparation for the nectochaeta stage each segment is slightly elongated, so that the parapodia are less closely crowded and can function as organs of progression.

Nectochaeta.—The head has begun to lose its larval features: its breadth is considerably less than before; the prototroch gradually disappears; the akrotroch is reduced in extent and becomes extremely difficult to distinguish—it probably consists of a single pair of minute tufts of cilia situated on the ventral surface near the middle line, in the angle formed between the umbrella and the anterior part of the head. By the end of this stage these remnants of the akrotroch, the prototroch, the ciliated area round the mouth, and the cilia by the crescentic eyespot, have completely disappeared. The three cephalic tentacles and the palps can now be distinctly seen projecting from the surface of the head—the lateral tentacles dorsally over the anterior, the palps ventrally over the posterior ends of the lateral lobes of the brain, and the median tentacle slightly in front of the lateral ones.

The thick-walled pouches of the oesophagus coalesce to form the muscular pharynx in which the rudiments of the jaws may be recognised as chitinous projections (Pl. I., fig. 18). The parapodia of the ninth segment have now attained the full development of their parts. On the peristomial segment one or two slightly curved and extremely stout serrate setae project between the dorsal and ventral tentacular cirri, whilst the remaining segments bear parapodia with both dorsal and ventral tufts of longer serrate setae (Pl. I., fig. 20), of which the ventral are longer and more slender than the dorsal.

A short line of 20μ cilia often occurs at this stage on the proximal part of either the dorsal or ventral surface of the ramus of each parapodium, and sometimes on both surfaces: similar cilia occur just in front of the bases of the peristomial cirri. Häcker (1896: p. 111, foot-note 2) notes the presence of intertrochal cilia on the dorsal rami of the parapodia of his Naples Polynoë larva. Rudiments of the tenth segment appear, but its parapodia remain very small and bear no setae during this stage, in which there is indeed very little development in the body region: and Häcker has already pointed out that it is a period of comparative quiescence. A median caudal appendage, 20μ long by 4μ broad, is now present.

Further development.—The nectochaeta stage of *Polynoë* is regarded as terminating soon after the disappearance of the ciliated band, when the size of the head is still further reduced and the tentacles and palps lengthen till their final proportions are reached; the body-segments elongate again and additional ones rapidly develop, so that, so far as general proportions are concerned, the worm becomes a small but perfectly normal Polynoïd before abandoning the pelagic habit. The cilia on the parapodia are often found in the very latest pelagic stages.

Häcker described the development of a species of *Polynoë* in 1894, and published a more complete and fully illustrated paper on the same subject in the following year (1895). He described the internal anatomy as well as the external characters of these larvae, and in general his account applies to the Port Erin species also. In his larvae, however, there were only seven primary segments, and no segment developed between the first appearance of these and the end of the nectochaeta stage. The same author described and figured the same (?) species of Polynoë larva from Naples (1897: pp. 77-8, Pl. III., figs. 1-2), and a species with nine primary segments from the Atlantic coast collections of the German Plankton Expedition (1898: pp. 8-9, Pl. I., fig. 1).

De Saint-Joseph (1895: pp. 196-198; Pl. XI., figs. 15-17; Pl. XII., figs. 25-26) also describes the metatrochophore and nectochaeta stages of a Polynoë with seven primary segments. The larvae of *Lepidonotus squamatus* described by Fewkes (1885: pp. 185-186; Pl. III., figs. 1-4; Pl. IV., figs. 14-17) have only four primary segments. The development of *Lepidonotus squamatus*—a species recorded from the L.M.B.C. area—has been described by Leschke (1903: pp. 129-130; Pl. VI., fig. 14; Pl. VII., figs. 1-2). The Trochophore is stated to have a violet pigment in the stomach walls, and a single pair of eyes of crescentic shape, two other pairs appearing later just as in the commonest Port Erin larva. Further development, however, shows the appearance of only seven primary segments: and in the specimen shown in fig. 1 of his Pl. VII. one of the three pairs of eyespots is situated behind the prototroch. In the late stage seen in fig. 2 of the same plate (a stage remarkably like the post-nectochaeta stage of the Port Erin larvae)—small tufts of cilia are described as occurring at the bases of the paired cephalic tentacles and palps.

McIntosh (1900: pp. 321-325; Pl. XXVIA, figs. 3-8, 10, and 12) describes and figures the pale greenish larvae of *Harmothoë imbricata*. He also (1900: p. 413) describes a larva, referred to a species either of *Sthenelais* or *Sigalion*, with bluish anterior digestive organs in the metatrochophore stage; whilst the larvae of *Phloe minuta* (described on p. 441) and of several unidentified species of Polynoidae (one described on pp. 325-6) are figured in the same work on Pl. XXVIA. Claparède has also described and figured Polynoë larvae (1863: pp. 80-81; Pl. VIII., figs. 7-11).

Phyllodocidæ.

Three kinds of larvae belonging to this family have been obtained. They all exhibit the same characteristic general appearance, but may be distinguished from each other by differences in the setae, and species *A* is of much smaller size than either of the other two.

Phyllodocid A. *Mystides* (Pl. II., figs. 6-7.)

Trochophore. This larva is very much commoner (during July) than either of the larger species. The Trochophore is of a pale brown colour and is extraordinarily contractile. When fully extended, the region in front of the prototroch is slightly longer than the region behind it, and the outline is roughly elliptical (Pl. II., fig. 6): when fully contracted the larva becomes broader than it is long, the transverse axis changing from 80 to 100μ, and the longitudinal axis from 160 to 80μ.*

The prototroch is probably double, with an anterior row of short, and a posterior row of long cilia, though as this was not investigated until after the trochophore stage had disappeared from the plankton, I can only describe it as such with certainty at a later stage; the long cilia are 100μ in length. In the largest Trochophores an eyespot of red pigment is present on each side of the prostomium, slightly on the dorsal surface, but I have been unable to find any cilia such as those described by Häcker (1896: pp. 84 and 85; Pl. III., figs. 8-9) just behind the eyes of his Phyllodocid larvae. Almost on a level with the eyes there is situated on the ventral surface, but apparently not always in the middle line, the "hook" of cilia stated by Häcker (1896: p. 84) to be characteristic of Phyllodocid larvae. These cilia (Pl. II., fig. 6; *Med. Hk.*) are 25μ long, but amongst them are a number of shorter cilia (15μ long) forming the posterior end of the median piece of a **T**-shaped akrotroch (Pl. II., fig. 6; *Akr*). The paired "hooks" of cilia present in species *C* have not been seen in larvae of the present species, in which, however, the details of the akrotroch are extremely difficult to make out. A scanty tuft of short straight cilia 7μ in length is situated at the apex of the prostomium.

The mouth is situated unusually far behind the prototroch, and is lined with cilia; these cilia are all curved inwards towards the oesophagus, and are not continuous with the longer cilia of the prototroch; they are, however, continuous with a neurotroch, the cilia of which are only 10μ long. This neurotroch is in the form of a narrow median band, as in many other larvae, for the anterior third of its extent, but broadens out further back into a somewhat diamond-shaped tract, as shown in Pl. II., fig. 6 (*Ntr.*). The posterior angle of this tract is extended to the anus, which is closely surrounded by short cilia similar to those of the neurotroch. The true telotroch—though frequently, if not always, present—is also of very short cilia; it does not completely encircle the body, there being a ventral break in its continuity, the neurotroch extending through this without coming into contact with the telotroch.

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* There is some reason to believe that "*Phyllodocid A*" as described here really includes two species. The first Trochophores found were slightly larger and more deeply pigmented than those from which these measurements were taken and which were first noticed on the following day. At the time I attributed this to the latter having appeared in the bay in a younger stage than any previously examined; but as there appear to be also two slightly dissimilar types amongst the older larvae, I am now inclined to attribute these differences to a difference of species. The smaller type of Trochophore lacked the pair of eyespots that was present in the larger.

The preoral (ganglionic) and postoral (subsequently segmented) deeply-staining cell-masses are much less conspicuous in these Trochophores than in those of *Polynoë*, and are very much smaller in the earlier than in the later phases of this stage.

Metatrochophore.—The first metatrochophore stage closely resembles the trochophore, but becomes somewhat larger, and the postoral deeply-staining cell masses are divided transversely into segments, of which the anterior are differentiated a little before the posterior. Although the segments thus appear in succession, it is possible to distinguish the seven that appear during the metatrochophore stage as primary segments, for their appendages reach an advanced state of development before any others are added. Very shortly after the appearance of segmentation, the appendages of these seven primary segments develop, and with this the second metatrochophore stage commences.

The peristomial segment bears a single pair of tentacular cirri; the second segment bears two pairs and a tuft of setae; and the remaining five segments bear uniramous chaetigerous parapodia, the first pair of these with a minute ventral, but no dorsal cirrus, and the rest with both a small dorsal and a small ventral cirrus. A pair of almost spherical anal styles develop at about the same time as these parapodia, and also the two pairs of cephalic tentacles, which appear close to the anterior end of the prostomium (as seen in Pl. II., fig. 7, of the nectochaeta stage) as extremely transparent conical outgrowths, about 40μ long.

The akrotroch with its unpaired "hook" is still present, its lateral extensions reaching very nearly to the cephalic tentacles. Two pairs of eyes are now present, one pair being smaller and slightly behind and on the inner side of the other, and embedded somewhat deeply in the tissues. The neurotroch and telotroch disappear before the end of the metatrochophore stage; but inter-paratrochal cilia appear—first on the ventral surface in tufts (10μ long), one below the base of each parapodium, and finally as complete amphitrochs (cilia 50μ long). The prototroch is still at the height of its development, and consists of an anterior row of short and a posterior row of long cilia. At the end of the metatrochophore stage the larva is 500μ long by 250μ broad; behind the seven primary segments an unsegmented region occupies about one-tenth of the entire length of the larva.

Nectochaeta.—The chief external changes that appear to take place during the remainder of the pelagic life of the larva are the development of additional segments from the anterior end of the anal unsegmented region, and the disappearance—shortly after this process has begun—of the akrotroch and oral cilia. Internally the pharynx becomes first clearly recognisable at this time: it is formed from a pair of pocket-like outgrowths of the oesophagus, as in Polynoë, but these only appear as thickenings of the wall of the oesophagus in whole mounts, and can rarely be seen at all until after the trochophore stage. The oldest larva obtained is in the fixed and slightly contracted condition 800μ long by 150μ average breadth; twelve intertrochal segments are present—their appendages bear slightly larger cirri than did those described in the previous stage. The dorsal cirri are more conical than foliaceous, but are stouter than the ventral. The setae are all jointed, and of the type shown in Pl. II., fig. *7a*; they are extremely transparent in balsam, and their exact shape is therefore very difficult to determine. The prototroch is still present, but the akrotroch and oral cilia, and probably also the interparatrochs, have disappeared. Only a single pair of eyes is present in this specimen; these are situated upon the dorsal surface of the head, and are dark brown and very opaque; by very strong transmitted light they are seen to be of a somewhat purplish brown colour. The pharynx is clearly marked, and joins the intestine between the fifth and sixth segments.

The four pairs of tentacles and three pairs of tentacular cirri show that this species belongs to the genus *Mystides*, Théel; whilst the arrangement of the tentacular cirri on the first two segments only is characteristic of the sub-genus *Mesomystides*, Cziernavsky. It is thus separated from *Mystides lizziae* (the only species of *Mystides* recorded by McIntosh in his Monograph of British Annelids) which belongs to the sub-genus *Promystides*, with one pair of tentacular cirri on each of the first three segments.

Phyllodocid B.—? *Eulalia*—(Pl. II., figs. 8-9.)

I have only been able to examine one specimen—a Nectochaeta—of this larva alive. In order to avoid confusion, all three stages will be first described from preserved specimens only, and the additional features seen in the one living specimen added at the end.

The two oldest (mounted) specimens show the characteristic appendages of a Phyllodocid, and another (a Metatrochophore) is undoubtedly a younger form of the same species as these, although no specially Phyllodocid features are visible. The remaining (mounted) specimen is a Trochophore, which shows a clear yellow pigmentation of the periphery, especially at the apical pole. The youngest of the three older larvae shows this clear yellow pigmentation in places, though not so extensively; the two Nectochaetae, like all other larval Polychaets obtained (excepting some of the Trochophores of the smaller species, "*Phyllodocid A*"), show no trace of it whatever: as, in addition, there is a general similarity of structure between the Metatrochophore and this Trochophore, and as the large size of the latter closely approximates to what would be expected of the trochophore stage of the former, it seems reasonable to refer them, provisionally at least, to the same species.

[Trochophore.—The Trochophore thus referred to is roughly spherical in shape, but its apical pole is somewhat flattened. Its greatest diameter is 350μ. The prototroch is strongly developed, and situated slightly above the equatorial plane. The mouth is surrounded by much shorter cilia. Paired anterior (ganglionic) and posterior (subsequently segmented) masses of deeply-staining tissue are present, and somewhat more conspicuous than in the Trochophores of *Phyllodocid A*; probably each of the ganglionic masses already bears an eye, but these cannot be at all clearly distinguished in the mounted specimen. Lateral (pocket-like ?) thickenings of the oesophageal walls (rudiments of the thick-walled pharynx) are already present. The walls of the stomach are quite free from opaque granules, no food being, however, discernible in any part of the gut.]

Metatrochophore II.—The only Metatrochophore seen already bears rudimentary parapodia (Pl. II., fig. 8). It is 650μ in length, and has a maximum diameter of 450μ, which now coincides with the position of the yellowish prototroch; the periphery in front of, and to a less extent also behind, this band shows a yellowish coloration, but not nearly so conspicuously as in the Trochophore. The preoral lobe bears a pair of conspicuous eyes on its dorsal surface. The mouth is still surrounded by cilia (Pl. II., fig. 8, *C. or.*); but the thickenings of the walls of the oesophagus have fused together in the middle line in front of the mouth.

Four pairs of tentacular cirri are present (one pair peristomial, two belonging to the second segment, and the fourth borne dorsal to the ramus of the first chaetigerous segment); they are all of about the same length (350μ). About ten further segments and a posterior unsegmented region are recognisable, each of the first six of these segments being provided with a short slender seta—either a simple capillary or the distal end only of a partially exposed jointed seta. Broad lobes, one above each chaetigerous lobe, represent the ultimately foliaceous dorsal cirri; anal styles are represented by short lobes originating behind a narrow telotroch.

Nectochaeta.—The last stage of this larva (that was seen) shows an increase in length to about

1,000μ, partly owing to the elongation of the segments already formed, partly to growth in the region of segment-formation; these specimens, however, appear to be less contracted than the Metatrochophore. The whole of the body is now segmented, though the two last segments (the fourteenth and the anal) do not bear parapodia. The remaining segments, however, especially those nearer the anterior end, bear appendages which show all the characteristics of those of the adult—foliaceous large dorsal and smaller ventral cirri, and a ramus bearing a tuft of jointed setae of the type shown in Pl. II., fig. 9. In some of the tufts a single capillary seta appears to be present also, but I have been unable to distinguish with absolute certainty between this and the appearance presented by the narrow edge of an unusually long distal segment of a compound seta, whose proximal segment is entirely embedded in the ramus of the parapodium.

The four tentacular cirri of the first three segments have developed unequally, those on the peristomial segment and the ventral pair on the second segment being now shorter than the other two pairs. The ventral cirri of the third segment are not tentacular like the dorsal ones, but resemble those of the succeeding segments.

The prototroch is still conspicuous, and the telotroch rather more strongly developed than in the previous stage.

The pharynx has almost assumed its ultimate character. The eyes are very conspicuous. Of cephalic tentacles, one pair is visible projecting sideways from the anterior end of the head; these are short, slender, and very transparent, so it is probable that a second pair is also present (as in the living specimen about to be described) obscured from sight by the tissues of the head.

Features of the living Nectochaeta.—The gut was of a clear green colour, and full of globules of some (nutritive ?) substance. The external tissues were brownish and more opaque, the anal segment being distinctly darker than the rest.

The prototroch consisted of long cilia 80μ in length—possibly there are shorter cilia as well. The cilia of the telotroch were 60μ long, and a complete amphitroch of 15μ cilia encircled every segment in a plane just behind the equatorial.

Two pairs of cephalic tentacles were present, one pair situated slightly anterior, and the other slightly ventral, to the eyes; they were short and transparent; no median tentacle could be distinguished. There appeared to be an akrotroch between the eyes, but this could not be seen at all distinctly.

Except for the absence of the median cephalic tentacle, these Nectochaetae closely resemble *Eulalia (Eumida) sanguinea,* a species that has been found at Port Erin in a condition of sexual maturity at about the time when these larvae occur, and to which they may belong: for although the median tentacle is one of the distinguishing characters of the genus *Eulalia,* it is conceivable that it might not develop until a later stage.

Phyllodocid C.—Only a single larva of this species was obtained. This has eleven pairs of parapodia; and now that the larva is fixed, the ramus of each parapodium is about twice the length of the thick conical dorsal and ventral cirri. In species *B*, which it resembles in size, the cirri project beyond the ramus in fixed specimens. No tentacular cirri are present, and the first pair of chaetigerous appendages appear to belong to the peristomial segment, characters which separate this form from all other Phyllodocids known to me. The setae resemble those of species *B*, but are slightly stouter. When alive, two pairs of short transparent tentacles could be seen close to the anterior end of the head, as in the other Phyllodocid larvae of this stage; these tentacles have completely disappeared from view now that the specimen is mounted.

There is a single pair of brownish eyes, and during life the mouth and prototroch were bordered with opaque black pigment, which was also present on the ventral surface of the prostomium, and, more abundantly, on the posterior surface of the anal segment. The gut was purplish in colour.

During life the cilia on this specimen were exceptionally easy to distinguish. The prototroch consisted of two rows of cilia, those of the anterior row being 20μ in length, and those of the posterior row 100μ. The akrotroch (Pl. III., fig. 39, A and B) was **T**-shaped, and its cilia were 20μ long; at the posterior end of its median limb cilia 40μ long were present between the shorter ones; they were not formed into the unpaired "hook" as in the larva of *Phyllodocid A*, but as their ends were beginning to macerate slightly, it is possible that they may normally be so arranged. The lateral pieces of the akrotroch curved backwards slightly, close to their origin, so as to pass behind a pair of well-defined "hooks" of 40μ cilia, and then curved forwards again as shown in the figure. Cilia were still present round the mouth, and a remnant of the telotroch remained on the dorsal surface of the anal segment. The neurotroch, however, was not present.

McIntosh (1869) has described the early stages of the development of *Phyllodoce maculata*; he figures a third-day Trochophore which is almost identical with the Phyllodocid Trochophores described above except in size.

McIntosh's larvae being very much smaller* than even Species *A* of the Port Erin Phyllodocids. Agassiz (1867: pp. 249-252; Pl. VI., figs. 46-55) describes the later development of this species. His youngest larvae (his figs. 46-47) already bear a pair of eyes and one pair of short cephalic tentacles. The first three body-segments—i.e., those that ultimately bear tentacular cirri—are at first much larger than the rest, which they overlap as a "shield." Greef (1879: pp. 255-6; Pl. XV., figs. 3-9) also describes a Phyllodocid larva with a "shield."

Häcker (1896: pp. 84-6; Pl. III., figs. 8-9) describes a short row of cilia just behind the eyes of his Naples Phyllodocid larvae in the trochophore and metatrochophore stages, stating (p. 85) that these are characteristic of Phyllodocid larvae generally, and serve amongst other characters to distinguish them from the larvae of *Polynoë* and of *Nephthys*. I have been unable to detect these in the Port Erin Phyllodocid larvae, whereas they are certainly present in Polynoid larvae (see above, p. 586).

I have already referred (see above, p. 575) to Mr. James Hornell's account of a Phyllodocid larva from the L.M.B.C. district. Other Phyllodocid larvae (all of them of the same general type as those from Port Erin) have been described by Claparède and Mecznikow (1869: pp. 189-191; Pl. XV., figs. 2-2D), Häcker (1898: pp. 11-12; Pl. I., fig. 5), and Leschke (1903: pp. 130-131; Pl. VII., figs. 3-5). McIntosh (1908: p. 45) briefly summarises the accounts given by some of the authors above referred to.

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* Specimens of the metatrochophore and nectochaeta stages of this species were abundant at Plymouth at Easter (1909), and I found them to be of quite a large size—about equal to that of Phyllodocids *B* and *C*. I have no doubt of the identity of these larvae, which closely agreed with Agassiz's figures, and which developed into small worms with all the characters of *P. maculata*; there must, therefore, be a considerable amount of growth between the stages reared by McIntosh from the eggs of this species and the early metatrochophore stages seen at Plymouth.

NEPHTHYDIDÆ (Pl. III., figs. 10, 11).

One of the commonest Polychaet larvae in the Port Erin plankton during July resembles closely in form and setae the well-known larvae of *Nephthys*, to which genus I have no hesitation in referring it. The examination of the living larvae was, however, insufficient, and I cannot give as complete an account of them as of some others. This examination was, moreover, confined to larvae in the nectochaeta stage, the metatrochophore stage being seen after fixation only.

Metatrochophore.—The youngest larvae seen are pear-shaped and 500μ in length by 350μ greatest breadth, this coinciding with the position of the prototroch. The mouth is certainly surrounded by short cilia. The lateral masses of nervous tissue in the preoral lobe are well developed, and the walls of the oesophagus are much thickened, but not pouched as in Polynoë larvae.

The body shows a posterior unsegmented region and seven primary segments (Pl. III., fig. 10), which as yet can hardly be said to bear appendages, though in segments 2-7 it is just possible to distinguish lobes representing neuropodium and notopodium, setae being just visible in the former, but barely projecting beyond the soft tissues. A telotroch is present.

During the second metatrochophore stage the umbrella is reduced to about 25μ diameter, and the appendages (with their setae) develop from before backwards, except for those of the peristomial segment, which arise much later than those of the second segment.

Nectochaeta.—This stage may be said to commence when the setae of the peristomial segment appear. The umbrella, as noted above, is now only 25μ in diameter, i.e., very little broader than the rest of the body. The prototroch consists of an anterior row of short

(20μ ?) cilia, and a posterior double row of unequal cilia as in the Syllid larvae described above. Of the latter row, those cilia which are directed forwards are about 80μ in length, and those which project backwards are much shorter (30μ ?). The length of the larva (which still shows the seven primary intertrochal segments only) at the beginning of the nectochaeta stage is about 700μ; its breadth (exclusive of the appendages) is 230μ. The first segment bears uniramous parapodia; the remaining six all show well-marked neuropodia and notopodia, each with a tuft of capillary setae, some of which are smooth, others frilled (see Pl. III., fig. 11A).

The posterior unsegmented region is longer in this stage, and bears a telotroch of 80μ cilia. A short median caudal appendage, transversely constricted in the middle, is present. The walls of the oesophagus are greatly thickened in this larva, and still stain very deeply.

A pair of almost black eyespots—purplish by strong transmitted light—is present on the dorsal surface of the head; and immediately behind them a conspicuous coiled tube is visible in living specimens. The mouth is small and inconspicuous; it is surrounded by a very narrow tract of 10μ cilia. A few cilia 15μ long are usually, but apparently not always, present at the base of the neuropodium, between this and the notopodium on every segment except, probably, the first two. Reddish-brown pigment is present on the ventral surface of the prostomium and on the anal segment; also, in a more diffuse form, on the intertrochal segments. The gut contains bright yellow globules, but is chiefly coloured by a bright blue pigment that is more intense at either end than in the middle of the body.

The oldest larva obtained is of about the same width as the last, but has increased in length to 800μ, and shows nine intertrochal segments; the secondary appendages are developing in regular series. The rudiments of a pair of tentacles can just be recognised in a pair of slightly projecting lobes at the sides of the head. Both the prototroch and telotroch are still well developed, and the intertrochal cilia between the lobes of the parapodia have been seen in a living eight-segment larva; the only nine-segment larva obtained was not examined alive, and so it is impossible to say whether they are present on it or not.

The complete development of *Nephthys* from the Trochophore has been described by Fewkes (1885: pp. 180-184; Pl. IV., figs. 1-12). He states that the mouth is situated, as in the larva of *Polygordius*, between an anterior and posterior ciliated band, the latter bearing shorter cilia than the former, but differing from that found in *Polygordius* in that it becomes indistinguishable from the anterior band laterally and dorsally. Leschke (1903: p. 131) has since proved this to be the case in a European species also. His posterior (post-oral) band is not present in the Port Erin larvae. Fewkes' oldest specimens—ten chaetigerous segments—show the development first of one and then of the rudiments of a second pair of cephalic tentacles, whilst dorsal and ventral "cirri" appear on each of the parapodia. A telotroch is present from the trochophore stage onwards, disappearing only in the very oldest larvae. Claparède and Mecznikow (1869: Pl. XIV., fig. 3), Häcker (1896: Pl. III., fig. 5; and 1898: Pl. I., fig. 4), Leschke (1903: Pl. VII., fig. 9) and McIntosh (1908: Pl. I., figs. 1-3) have also described Nephthys larvae. McIntosh's larvae (pp. 14-16) at least seem likely to belong to the same species as do those found at Port Erin during July.

EUNICIDÆ (Pl. I., fig. 21).

A Eunicid Metatrochophore has been twice seen. It differs from all other larvae here described in that it bears the cilia characteristic of a Protrochophore, the true trochophore stage having been omitted from its life history.

The larva (Pl. I., fig. 21) is ovate; it is 300μ long by 180μ broad; and is invested in a thick ornamented cuticle, the ornament being, however, no longer visible when the specimens have been mounted in balsam. Cilia 15μ long project beyond the cuticle all over the body with the exception of a narrow tract round the apical tuft of 30μ cilia, and a somewhat larger area round the anus. Close to the posterior border of the broad ciliated region there is a pair of lateral tufts of 30μ cilia.

At the apical pole the cells take a deep stain; behind this there is a faintly-staining tract; and behind this again, on the ventral surface, there is another deeply-staining area, in which can be distinguished the outlines of the three primary segments and the formative region, the last being quite narrow in the younger of the two specimens, but almost as broad as one of the primary segments in the older of the two. Behind this, finally, there is in the older larva at least, a narrow band of clear tissue surrounding a cluster of deeply-staining cells at the extreme posterior end.

A number of short straight rods were seen during life directed towards the surface under the cuticle at the anterior end of the larva. A pair of red eye-spots were present near the anterior end. The gut was tinged with traces of a pinkish pigment, and contained large clear globules.

In the older larva at least, setae project from three pairs of cavities in the cuticle; these setae can be retracted into pits in the body-wall. They are all compound, but do not now show sufficiently clearly in balsam to allow an accurate drawing to be made.

Eunicid Metatrochophores very similar to the above have been described by Häcker (1896: pp. 78-9; Pl. III., figs. 3-4, and 1898: p. 9; Pl. I., fig. 2). His 1896 paper includes a description and figure of the Nectochaeta, as well as the Metatrochophore of the Naples species.

Other Eunicid larvae have been described by Claparède and Mecznikow (1869: pp. 182-4; Pl. XV., figs. 1-1H—? *Lumbriconereis*. And pp. 184-186; Pl XII., figs. 2-21—*Ophryotrocha*). Wilson (1882: pp. 288-291; Pl. XXI., figs. 89-92; Pl. XXIII., fig. 10—a very complete account of the development of *Diopatra cuprea*), Fewkes (1885: pp. 197-201; Pl. VII. and Pl. VIII., figs. 1-3—*Lumbriconereis*; stated to be generically different from the ? *Lumbriconereis* of Claparède and Mecznikow), Braem (1893: pp. 217-221; Pl. XI., figs. 32-36—*Ophryotrocha*) and Korschelt (1893: pp. 237-242; Pl. XIII., figs. 12-15—*Ophryotrocha*). All these larvae agree in the suppression of the trochophore stage; but this is apparently due to the first portion of their development taking place within a mass of jelly, and is not at all exclusively characteristic of the Eunicidae (see Häcker, 1896). With the exception of *Ophryotrocha*, there is, however, a marked resemblance between them in general form.

II.—SPIONIFORMIA.

The larvae of Spioniform worms (with the exception of the Chaetopteridae, whose well-known " mesotrochal " larvae form a well-defined group), are characterised by the presence of long capillary provisional setae, of which those of the first segment considerably exceed the others in length, and often appear in the trochophore stage. The segmented larvae are in general much more slender than those of the Nereidiformia, and the characteristic pair of tentacles usually begin to develop immediately behind the prototroch, at an early stage.

SPIONIDÆ.

Spio. (Pl. III., fig. 38).—Metatrochophore.—The youngest larvae seen are of a small size (300μ by 100μ), and bear three pairs of very conspicuous black eye-spots that are very resistant to the solvent action of spirit. The eyes may be arranged in a straight line with the large, somewhat crescent-shaped pair at the sides of the head and the other two pairs nearer the middle-line on the dorsal surface; or their position may, in the same specimen, change so as to present the arrangement shown in Pl. III., fig. 38, or some intermediate pattern.

Each segment bears a tuft of exceedingly long and slightly curved setae, which are held parallel to the sides of the body when the larva is swimming, but when it is irritated they project from the body as shown in Pl. III., fig. 38. These setae are minutely serrate on the convex side, but the serrations are quite indistinguishable in a balsam mount. As the larva grows they increase in length also, so that the longest ones are always found to be about twice the length of the body. The oldest larva seen has eight segments, and is 550μ in length.

The observations upon this larva during life are not sufficiently complete to allow of the structures then seen being adequately figured; but apical cilia and (incomplete?) interparatrochs are certainly present. The prototroch seems to be invariably composed of shorter cilia (40μ) than the telotroch (50μ). The course of the prototroch is interrupted in the middle of the dorsal surface (see figure). It is continued downwards, to end ventrally on each side on the lips that border the capacious "mouth." The formation of these lips shows that it is not the mouth of the Trochophore, but is the external aperture of a vestibule from which the original mouth still opens into the oesophagus. This structure, which further involves the modification of the ciliated bands on the head and anterior segments, appears to be characteristic of larvae of the Spionidae and Polydoridae. It is described for several of these larvae in another paper (Gravely, 1909).

This larva resembles certain known larvae of *Spio*—so closely as probably to be of the same genus—perhaps also of the same species as some. Of these larvae, one reared from the ova of *S. fuliginosus* is figured by Claparède and Mecznikow (1869: Pl. XII., fig. 1M; and Cambridge Natural History, Vol. II., fig. 145B, p. 275) with its setae, which are not quite so inordinately long as in the Port Erin form, held as when swimming. In the larva of *S. mecznikowianus*, also figured by these authors, the gut is enormously swollen with food-yolk, the larva being at first carried about attached to the body of the mother. The larva of *S. seticornis* described by Leschke (1903: pp. 122-3; Pl. VI., figs. 7-9) and the *Spio* larva described by Häcker are both very like the Port Erin form above described.

Spionid A ("Claparède's unknown larval Spio") (Pl. II., figs. 22-27).—A transparent, colourless larva, originally described by Claparède (1863: pp. 77-80; Pl. VI.) and subsequently—under the name quoted above—by McIntosh (1894: pp. 71-74; Pl. VIII., figs. 4-7), is very abundant in almost every tow-netting taken at Port Erin during July. Although I am able to describe a later stage in the development of this larva than either of the above writers have done, its identification with an adult form still remains an unsolved problem.[*]

Nectosoma.—The earliest stage obtained was 700μ long by 200μ broad. It shows a posterior unsegmented region preceded by about ten somewhat indistinct segments. The first of these is provided with a tuft of long straight setae, and the others with shorter but otherwise similar ones; no neuropodial setae are present as yet. The body-wall is thin dorsally, but thicker ventrally. The gut is broad, and contains a (yolky ?) substance of finely granular appearance and faint staining properties with borax-carmine. No food-material from the exterior has been seen in the gut in the earlier stages. The head is rounded in front, and after fixation is almost always ventrally flexed. Young specimens examined alive bore two pairs of red eye-spots on the dorsal surface of the head, the inner pair being situated somewhat behind the outer pair. They also showed a spot of opaque yellow pigment at the base of each tuft of setae; these spots were smaller towards the anterior end of the larva than they were towards the posterior end; and a line of minute specks of the same opaque pigment was found to extend across each segment between the spots situated on either side of it.

The larvae elongate by the continuous development of new segments, and the boundaries of the old segments become more clearly defined. The neuropodial setae soon appear, the first of each tuft to develop being very much stouter than the rest, which resemble those already present

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[*] Dr. Allen has called my attention to the fact that Claparède himself subsequently described (*Zeits. wiss. Zool.*, XXV., 1874—included in a paper by Ehlers) fragments of a worm which he recognised as the adult of this larva, and for which he founded the genus *Poecilochaetus*, a genus separated from the Spionidae by Mesnil and placed in his new family Disomidae. Dr. Allen has since fully described a species of *Poecilochaetus* (*Quart. Journ. Micr. Sci.*, XLVIII., 1904).

in the dorsal tuft. Before long a similar stout seta appears in the dorsal tuft, and two may be present in the ventral one. The most anterior segments, however, seem to be without these stout setae.

In a larva of about twenty segments (1,500μ long) a pair of lobes, the rudiments of the tentacles, are clearly indicated at the sides of the head, and parapodia, slightly biramous, already project from the surface of the body, though more usually this occurs in larvae of about twenty-five segments. The tips of both lobes of the parapodia are faintly tinged with brown; and each of the masses of opaque yellow pigment above mentioned is now situated between the bases of the two lobes of a parapodium (Pl. II., fig. 27). The individual segments lengthen considerably at about this time, and the tissues lose the strikingly embryonic appearance that they have so far possessed, at all events after staining. This is due in part, no doubt, to the disappearance from the gut of its (yolky ?) contents referred to above; only occasionally, however, has any food material from the exterior been seen to replace this substance.

The head and anterior segments show, in an intensified form, the structures briefly noted above (p. 607) as characteristic of larvae of Spionidae and Polydoridae. There are no nototrochs; gastrotrochs, however, are present on every segment, but become smaller, and finally disappear towards the posterior unsegmented region. The gastrotrochs of the first three segments are modified in connection with the special characters of the head; those of the remaining segments consist on each side of an outer and middle row of 40μ cilia, and an inner row of 15μ cilia; the inner rows of the two sides of one segment do not extend to the middle line, but are separated by a short gap, as are the other parts of the gastrotroch. There is a short median dorsal gap in the powerful telotroch.

The dorsal and ventral rami of the parapodia increase in size, whilst the pigment spots between them decrease. When about thirty segments have appeared, the parapodial rami of segments 7-11 (inclusive) rapidly lengthen till they become 200μ long, those of the other segments retaining a length of about 100μ; the former are now shaped like a long-handled club, attached by the thick end (Pl. II., fig. 26, shows one of these parapodia from a still more advanced worm); the latter lack the " handle," and are simply pear-shaped.

In this connection it may be noted that the correlation between the development of any particular organ and the number of segments then present is remarkably small, and Claparède figures a forty-segment specimen with uniform appendages. When about forty segments have been formed the Port Erin larvae are found to have developed a pair of large tentacles that project conspicuously from the sides of the head; between them the dorsal surface is compressed laterally so as to give the head a crested appearance. All cilia disappear from the larva, with the exception of some situated in a pit on the ventral side of the second segment, and a row placed obliquely on each side of the median dorsal crest of the head.

Further specialisation of the appendages takes place. The first segment (Pl. II., fig. 23) bears on each side as before a bunch of much longer setae than the following segments; immediately behind these setae, and apparently belonging to the same segment, is a short (40μ) notopodial projection, below which is a small (30μ diameter) spherical protuberance, which during life bears straight delicate (sensory ?) processes; and immediately behind this protuberance is situated a tuft of short (800μ) setae, and a long (130μ) neuropodial projection. The second and third segments (Pl. II., fig. 24) each bear a long (130μ) notopodium immediately behind a bunch of short (500μ) setae; and a neuropodium of the same dimensions as the notopodium. Immediately in front of the neuropodium is a tuft of setae consisting of a single straight seta, and first one, then two, and in the oldest specimen of all (in the anterior of these segments at least) three shorter stout curved setae. Between the dorsal and ventral rami there is a small round protuberance bearing hair-like processes as on the first segment. The fourth, fifth and sixth segments (Pl. II., fig. 25) resemble the second and third, except as regards the ventral bunch of setae, which consists of two straight stout spines and three or four much smaller ones; the small rounded protuberance, moreover, is not invariably present on all these segments. The next five segments (Pl. II., fig. 26) resemble the last three, except that both neuropodium and notopodium reach a length of about 200μ, being produced distally, as mentioned above, into a slender cylindrical "handle"; one of the dorsal setae, too, is markedly stouter than the rest, resembling the two strong setae of the ventral bunch. The remaining segments also show this stout dorsal seta, but otherwise resemble segments 3-5; after the first four or five of them, however, the occurrence of these special setae becomes irregular, and still nearer the posterior end they are not to be found at all.

Two fixed specimens—one incomplete at the posterior end, the other with forty-two segments—show the anterior unpaired process of the head (Pl. II., fig. 22) developing to a large size; its distal end is flattened, but not bifid. McIntosh (1894: p. 73) remarks that none of Claparède's or his own specimens showed this conspicuously, and suggests that it might be expected later to attain a much greater size. These two larvae appear to be considerably older than any described by either Claparède or McIntosh, as these authors make no mention of the short curved setae of segments 2-3, which would seem to develop some time before the growth of the anterior prolongation of the head.

I have seen nothing, even in the oldest larvae, of the two rudimentary cirrus-like outgrowths that occurred on each parapodium of the second and third segments in a specimen described by Claparède from Christiansand Harbour (1863: p. 79; Pl. VI., figs. 8-9). Probably these were, as he suggests, abnormal.

Spionid B (Pl. III., figs. 33-34).—Nectosoma. This larva is characterised by its slenderness, the anterior segments of a well-expanded specimen being quite as long as they are broad.

The youngest specimen examined (800μ by 80μ) shows ten segments and a posterior unsegmented region; the appendages scarcely project, and the setae, which are long and slender, have become so much folded round the body in mounting (this larva was not examined alive) as to make further observations upon them impossible. The head is rounded in front and already bears two pairs of eyes, a small pair situated on the dorsal surface not far from the middle line, and a larger pair situated at the sides of the head or slightly on the ventral surface. Prototroch, telotroch, and intertrochal cilia are present, but their extent cannot be determined. Close to the anus there is a pair of very characteristic groups of anal styles (Pl. III., fig. 34; *An. sty.*). Later stages show the growth of the worm by the addition of further segments; a very conspicuous pharynx appears (Pl. III., fig. 33; *Ph.*), the tentacles develop, and both notopodia and neuropodia begin to project from the sides of the body. A mounted larva of twenty-two segments (total length $2{,}100\mu$, breadth 150μ) shows the setae very clearly (Pl. III., fig. 33). Those of the (single ?) tuft on the first segment reach a length of 450μ, whilst those of both dorsal and ventral tufts on the second and third segments are not more than 80μ long; the fourth and succeeding segments bear setae 300μ long, these being less numerous on the fourth than on the remaining segments; they are provisional setae that are shed from the anterior segments—with the exception of the first—before they disappear from the posterior ones. The provisional setae of the first segment disappear very soon, however, and those of the remaining segments continue to be shed, from before backwards. The permanent setae become more numerous, and hooded crotchets make their appearance in the ventral tufts of setae on the tenth and succeeding segments, being most numerous near the posterior end. The branchiae and podal membranes develop in series beginning on the second chaetigerous segment.

My observations upon this larva in the living condition were confined to the stage in which the tentacles, though present, are still rather short. The usual Spionid characteristics of the anterior end (see above, p. 607) are present. The prototroch extends along the bases of the tentacles. The head presents a crested appearance, as in the advanced stages of *Spionid A*. Gastrotrochs, broken into four equal sections, are present on every segment, with the possible exception of the first three as in "Claparède's larva" (see above, p. 609). The telotroch is incomplete dorsally, as in other Spionid larvae. The tentacles of this larva, as well as its slender vermiform appearance and long provisional setae, show it to be undoubtedly a stage in the development of a

Spioniform worm; it differs, however, from all the figures I have seen of such larvae in the length and narrowness of the segments, and the consequent extreme slenderness of the larva as a whole. Otherwise it is not unlike the larva of *Nerine* figured by Agassiz in 1867 (see his Pl. VI., figs. 40-42) and de Saint-Joseph (1894: p. 69; Pl. III., fig. 80). The generic characters (see Mesnil, 1896, p. 117) of our larva up to the latest stage examined are those of *Microspio*, Mesnil, but as several of these are negative its position cannot be regarded as definitely established.

[**Nerine.**—An early stage of *Nerine cirratulus* is very common at Port Erin, more especially, Mr. Chadwick tells me, in the earlier part of the year. I have not yet been able to make any detailed observations upon it, although I have frequently seen it in the July plankton; and I have not been able to trace its history after the loss of the conspicuous vitelline membrane with which these early stages are invested. Its identity has been determined by Cunningham and Ramage (1887: pp. 638-9), who recognised this vitelline membrane with its characteristic external reticulum of hexagonal meshes to be the same as that originally described by Claparède (1868: pp. 329-330) surrounding the ova of *Nerine cirratulus*.[*] These authors describe the segmentation of the egg and the development of the Trochophore, which still bears the characteristic vitelline membrane (Pl. III., fig. 39, C) through which pass the cilia of the prototroch, telotroch, and apical organ. Two pairs of chaetigerous parapodia begin to develop before the vitelline membrane disappears; the setae of the anterior pair are, as is usual

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[*] I have found a similar membrane round the eggs of *Scolecolepis vulgaris*; so these larvae may belong to either of these worms, and perhaps to others also.

in Spioniform larvae, much longer than those of the second pair. Leschke (1903: p. 103; Pl. VI., fig. 10) has also described the Trochophore of this species; his account is in close agreement with that of Cunningham and Ramage. Claparède and Mecznikow (1869: Pl. XII., fig. 4) figure a two-segment larva of this species, still invested in the vitelline membrane; it is apparently of about the same age as that figured by Cunningham and Ramage in fig. 2 G of their Pl. II. Claparède and Mecznikow state that the further development is broadly the same as that of "*Nerinen* (fälschlich *Leucodoren*) Larven von Normandie," and only figure one other stage, this having over thirty segments. This larva is at once distinguished from the Spionid larvae of the present paper by the large prickles on the provisional setae of the first segment. The figures given by Cunningham and Ramage (loc. cit.: Pl. XXXVII., figs. 2 I, 2 J) show "a later stage [12-segments: not described in the text] of the larva" of *N. cirratulus* which has developed along very different lines from this larva, but resembles in some detail the larvae of *Polydora* (see below, p. 627).]

Spionid C. (Pl. III., fig. 35). This is an extremely common form, characterised by its small size (about equal to that of similar stages of the *Spio* described above), long slender setae, and single pair of eye-spots, which are situated slightly on the ventral surface and which always disappear in spirit. I have only been able to make a hurried examination of the living larva.

Metatrochophore.—The head is rounded and bears a tuft of apical cilia and one pair of red eye-spots. The prototroch is probably still complete at this stage, as the characteristic cephalic larval organs of the Spionidae do not seem to have developed as yet; it encircles the larva in its broadest part, which is 150μ in diameter.

Behind it successive segments are formed, narrow at first, but becoming broader as they develop: each bears a dorsal tuft of long (240μ) setae, and a ventral tuft of shorter ones (80μ), the latter appearing on each segment a little later than the former. The lengths of these setae show a steady decrease from the first segment to the posterior end. Gastrotrochs were seen in the living larva, but their precise extent was not determined.

The dorsal body-wall is thin as usual, and contains a pair of conspicuous longitudinal muscle bands; the ventral wall is thicker, and even in quite small larvae (seven segments) shows traces of the differentiation of the nerve-cord which, during the development of the next two or three segments, becomes quite clearly defined. The gut, even in the earliest stages seen, contains the remains of unicellular organisms. No distinctive permanent features have been seen in this larva, only the metatrochophore stage having been found. On account, however, of the long setae and slender body it may be referred with certainty to the Spioniformia. It can hardly be an early stage in the development of *Spionid A* because, in addition to its relatively small proportions, the gut always contains abundant remains of unicellular organisms and never the yolky (?) material there present. From *Spionid B* it is distinguished by the shortness of the segments relatively to their breadth: the setae, too, are slightly stouter and more rigid.

Spionid D. "Chaetosphaera" (Pl. III., figs. 36-37).

Metatrochophore and Nectosoma.—This is a very large form, which is characterised by its tufts of strong, smooth, and slightly curved setae (Pl. III., fig. 36), and by the prolongation of the head into a snout which, however, is usually contracted out of all recognition in fixed specimens (compare Pl. III., figs. 36 and 37).

This snout appears to be formed from the anterior margin of the head and lips, and is a peculiar modification of the cephalic larval organs characteristic of the Spionidae.[*] Sections have revealed the presence of a curious (sensory ?) organ, situated on the fore part of the head in the mid-dorsal line immediately above the brain. Behind this are situated the eye-spots, which are of a reddish colour and somewhat opaque.

Nototrochs are absent. The gastrotrochs of the anterior segments are as usual modified in connection with the special structures of the head. The fourth and succeeding segments, however, each bear laterally an inner and outer pair of short rows of extremely powerful 100μ cilia on the ventral surface; whether any cilia were present nearer to the middle-line it was impossible to determine on account of the extreme opacity of this region in the larvae examined. These gastrotrochs became smaller and finally disappeared altogether towards the posterior end of the body. The cilia of the telotroch were much longer than those of the prototroch, the former being 120μ long, the latter only 60μ. The tentacles develop at a very early stage, and the prototroch extends along their bases (Pl. III., figs. 36-37, *Ptr.*). The gut consists of a muscular pharynx followed by a broad intestine which is filled with a very opaque yolky material; the walls of the gut often contain dense black pigment.

The provisional setae are very stout and distinctly curved. Those of the first segment reach a length of 300μ, those of the remaining segments a length of 200μ; they are confined to the dorsal lobe of each parapodium, and appear before the parapodia begin to project from the body-wall. The ventral setae develop later; they are

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[*] It has been described elsewhere (Gravely, 1909).

short capillaries, and separated from the dorsal tuft by a small conical process which precedes them in development. These parapodial structures are well shown in a mounted larva, of about 17 segments, which is 1,300μ long by 300μ broad; many of the ventral setae have reached a length of 90μ; they are smooth (?), stout, and slightly curved, and occur three or four to each tuft, the provisional setae being still present in the dorsal tufts. In another larva of about the same age most of the provisional setae have been shed from all segments (except the first) of the anterior half of the body, their place being taken by permanent dorsal setae resembling those of the ventral tuft in which the development of provisional setae appears to be entirely omitted. In this specimen crotchets are present in the ventral tufts of the thirteenth and succeeding segments; the gut is still full of opaque yolky material.

These larvae probably belong to the same species as the "Larve mit rüsselartiger Oberlippe" figured by Claparède (1863: Pl. VII., figs. 1-2) and briefly described in a foot-note to p. 86 of the same work. The unpaired dorsal (sensory ?) organ on the fore part of the head is indicated in his fig. 2.

Another species of larva* showing the same remarkable modification of the head, and the same arrangement of the ciliated bands, occurs in the Plymouth plankton at the end of March and beginning of April. Many of the setae of this larva are very much stouter than those of *Spionid D*; some of them are smooth, and others serrate, the former presenting a variety of form strongly suggestive of the figure given by Häcker (1898: Pl. III., fig. 21) of one of the larvae for which he created the provisional (larval) genus "*Chaetosphaera.*" The stout and diverse form of the setae, together with the habit which the Plymouth larva shares with *Spionid D* of contracting and curling up into a more or less spherical spinose mass when irritated, proves conclusively that the Plymouth larva is a true "*Chaetosphaera,*" and from this it may be inferred that the peculiar structure of the head found in the Plymouth larva and in *Spionid D* is one of the characteristics of the genus. As Häcker was only able to examine preserved specimens, it is not surprising that he saw nothing of this. The simpler stout setae which alone are found in *Spionid D* bring this larva nearer to the species of "*Chaetosphaera*" figured by Häcker (loc. cit., p. 20) in his text-figs. C and D; this, however, bears serrate setae anteriorly, whereas the setae of *Spionid D* are all smooth.

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* These observations on *Chaetosphaera* were made after the above account of *Spionid D* had been written. As this paper in its original form is frequently referred to in my 'Studies on Polychaet Larvae' (Gravely, 1909) it seems best to add this note rather than modify the original account.

A specimen of another species of "*Chaetosphaera*" was obtained by Prof. Herdman at Port Erin in April, and this he kindly sent on to me; but as it is at present only known by this one preserved specimen I cannot give a full description. The general form of the body is like that of *Spionid D*, but the "snout" is of course contracted beyond recognition. Most of the setae resemble those of *Spionid D* in form, but are serrate instead of smooth; amongst these a single broad, flat, and somewhat curved seta, with rather finely serrate edges occurs in some of the dorsal tufts. Though broad at the base it becomes much broader distally, and then rapidly tapers to a point, the outline of the tip consisting of a pair of somewhat concave curves. The eyes are four in number.

With regard to the adult form of "*Chaetosphaera,*" it is interesting to note that a slender median tentacle, inserted ventrally in the dorsal sheathing portion of the prostomium, was found to be developing in the oldest of the Plymouth larvae that were seen. A tentacle in this position is found in the Spioniform worm *Poecilochaetus*, but any close affinity with this genus is rendered improbable by the entire absence from the larva of *Poecilochaetus* (*Spionid* A of this paper)—unless it be in the very early stages prior to that in which it first appears in the tow-net—of the cephalic structures characteristic of the "*Chaetosphaera*" larva. At present it is impossible to identify the larval genus "*Chaetosphaera*" with any known adult genus, but the many points of resemblance between this genus and the larvae of *Spio* and *Polydora* sufficiently prove it to belong to the Spioniformia.

POLYDORIDÆ.

Polydora.—Metatrochophore (Pl. II., fig. 31).—A species of Metatrochophore resembling that described by Claparède (1863: pp. 69-70; Pl. VII., figs. 4-6) as the young of *Leucodora*, Jnstn. (=*Polydora*, Bosc.) *ciliata* was obtained on several occasions; in no case, however, have I seen a specimen intermediate between these larvae and either form of *Polydora* Nectosoma described below. None of these Metatrochophores have been examined alive; when fixed they appear to be very much contracted. A 5-segment specimen is 350μ long, its maximum breadth (300μ) occurring in the body-region. The head is large, and almost hemispherical in shape; it is 200μ broad posteriorly, and bears the rudiments of a pair of tentacles. Claparède, in his 5-segment stage, figures a powerful prototroch and telotroch, a band of shorter cilia situated on the fifth segment, the rudiment of a neurotroch on the first two segments, and a pair of short tufts of cilia on the anterior margin of the head. His larvae are certainly not specifically identical with the Port Erin ones however, and whether these structures are also present in them is yet to be ascertained. The first segment of the Port Erin larvae is longer than any other and bears a pair of tufts of long (850μ), stout, curved, ringed setae (Pl. II., fig. 31), with a short parapodial process in connection with each. The remaining intertrochal segments each bear a discontinuous transverse band of black pigment. They are usually devoid of setae; but in one larva a single pair is present on the fifth (?) segment; these two setae are much shorter and more slender than those of the first segment, and they appear to be quite smooth. Claparède figures ringed setae on all segments in his 5-segment stage (loc. cit., fig. 6), those of the four posterior segments being about half the length of those of the first segment; he also figures the pigment as a stellate patch on each side of the four posterior intertrochal segments, and not in transverse bands as in the Port Erin larva.

Nectosoma.—Two species of *Polydora* have been found in the nectosoma stage. One of these (described under the name "*Polydora B*") bears pigment arranged, roughly, in transverse bands (see fig. 32); it is possible that this may be a later stage of the Metatrochophore above described, but as all the specimens obtained show 15-20 chaetigerous segments it is impossible to find any certain evidence of this. The other species is much commoner and is characterised by stellate pigment-patches, arranged in a row down the middle of the dorsal surface of the body. As much more complete series of these larvae have been found it will be convenient to describe this species (to be referred to as *Polydora A*) before the other.

Polydora A (Pl. II., figs. 28-30). The youngest specimen obtained is 580μ long by 150μ broad, and has nine segments. A short conical parapodial outgrowth is present immediately below each tuft of setae. The setae are smooth capillaries, those of the first segment being decidedly longer than the rest. The tentacles have not yet developed, which proves that this is not a later stage of the *Polydora* Metatrochophore described above. The head bears three pairs of eyes enmeshed in a reticulum of black pigment (as in Pl. II., fig. 28, a later stage). Black pigment is present at the sides of the body, between the tufts of setae; on the third, fourth, and fifth segments a black band passes dorsally from each of these lateral patches, the anterior pair almost meeting in the middle line (as in Pl. II., fig. 28). On each of the remaining segments these bands are replaced by a median ramified patch; the posterior end of the anal segment is tipped with similar black pigment. No black pigment is present on the ventral surface. In a 12-segment larva the arrangement of the pigment is as before, but the ramified patches are much larger. A few provisional setae of the ventral tuft are beginning to project in addition to the dorsal ones on some of the anterior segments. It appears to be usual for the ventral provisional setae of Spioniform larvae to develop later than the dorsal ones, and to remain smaller than them (for other instances see *Spionids A, C, D*, above).

The tentacles appear as a pair of short conical outgrowths behind the prototroch (which does not extend along their bases) in a 17-segment stage. This larva is represented in fig. 29. It will be seen that the arrangement of the pigment remains very much as before. The fifth segment shows, embedded in the tissues, the faintest rudiments of its specialised permanent setae, and has already lost a number of its provisional ones, though none of the other segments appear to have lost any of theirs.

In an older larva ($2{,}000\mu$; 23 segments) the specialised setae of the fifth segment are much more conspicuous and project slightly, almost all the provisional setae having been shed from this, and from the first, second, and third segments. The tentacles are much longer and appear to arise nearer the middle line than in the younger specimen. In addition to this, the parapodia of the seventh and succeeding segments each bear a short (30μ) dorsal outgrowth—the rudiment of the gill—and amongst their ventral setae a single hooded crotchet has appeared. The lateral extensions of the first three or four median ramified patches of pigment are now emphasised by a considerable reduction of the other parts, and the lateral patches are in some instances extended for a short distance on the ventral surface. The four most recently formed segments are pigmented on the same plan as segments 3-5, the lines of pigment, however, ramifying somewhat over the segments. The five pharyngeal pouches described in detail by Salensky (Bull. Imp. Acad. Sci., Moscow, 1908) reach the height of their development at about this stage.

In the oldest specimen seen (25 segments) these pouches are disappearing again; the special setae of the fifth segment project as shown in Pl. II., fig. 30. I have been unable to identify them with those of any adult form. The shedding of the provisional setae has not progressed so far as in the previous specimen. In both these larvae, and in all others of sufficient age a number of segments, increasing with the growth of the body and commencing with segment 9, contains a deeply staining granular substance, which, in balsam preparations of whole specimens stained with borax-carmine, closely resembles developing spermatozoa.

The anterior end is modified in connection with the vestibule characteristic of larvae of the Spionidae and Polydoridae.* On the third segment a tuft of 80μ gastrotrochal cilia is present on each side close to the ventral setae; segments 5, 7, 10, 13, 15, 17, etc.—*not* strictly alternate segments anterior to the 13th—each bear a gastrotroch which consists of two kinds of cilia, a row of short (45μ) cilia extending across the middle part of the segment between two lateral rows of powerful (80μ) cilia, with which it is continuous at each end; in the more advanced larvae examined the gastrotroch of the highly specialised fifth segment, but of no others, was found to be undergoing reduction. Nototrochs are absent from the first two segments, but on all the others a line of 60μ cilia is present on each side; whether these are joined by a line of shorter cilia across the middle of the segment to form a complete nototroch I was unable definitely to determine. The cilia of the prototroch, which does not extend along the bases of the tentacles, are 80μ long; those of the telotroch, which is incomplete dorsally, are 100μ long.

Polydora B (Pl. II., fig. 32). This is most easily distinguished from *Polydora A* by the arrangement of the pigment which is more diffuse, and lacks the characteristic stellate appearance. A change in the pattern on each segment is noticeable in passing from the anterior to the posterior end of the larva. The first segment bears a pair of irregular black patches; subsequent ones bear a more or less continuous posterior transverse band of pigment, which becomes more broken

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* See Gravely, 1909, pp. 610, 611.

in the posterior segments, where, in addition, a row of irregular black patches is present in front of each.

The only other known *Polydora*-larva whose pigmentation is at all like this is figured by Häcker (1898: Pl. II., fig. 16). Three pairs of eye-spots are present, the inner- and outermost pair being larger than the middle pair; a small reticulate patch of pigment is present beside each eye of the outermost pair, but this does not extend amongst the eyes as in *Polydora A*. The ventral surface is free from this black pigment. Apparently no specimen obtained is old enough to bear crotchets; the stout setae of the specially modified fifth segment are, however, very evident, although the larvae have only 17 segments, at which stage this segment is almost unmodified in species *A*; capillary setae are still present on this segment. The specialised setae are very like those of species *A*. One larva of species *B* was examined alive; the cilia are arranged as in species *A*.

Claparède, as above mentioned, has described the development of larvae which he believed to be those of *Leucodora*, Jnstn. (=*Polydora*, Bosc.) *ciliata*. Agassiz (1867: pp. 242-3) disputes the identity of these larvae with this or any other species of the genus *Polydora* on account of the complete absence of the special modifications of the fifth segment, even in the oldest larvae; and he goes on to describe the development of a species of Polydora—probably, he thinks, *P. ciliata*—from an 11-segment form (loc. cit., Pl V., fig. 26), in which "the fifth ring is much wider than any other, and has only three short, stout bristles on each side" (loc. cit., p. 244). Agassiz's main contention, however, falls to the ground in view of the fact that Claparède's oldest larva possessed only 17 segments, at which stage, as noted above, it is only after a careful examination with a high power, of a transparent mount, that traces of the special modifications of the fifth segment can be distinguished in *Polydora A*. Thus the stage at which these structures appear may be much later than was the case in the larvae examined by Agassiz: and this variability has also been noted by Häcker (1898: p. 17) in connection with certain species described by him. Apart from the question of the fifth segment, however, Claparède's 17-segment larva is much more fully developed than even the most advanced of the Port Erin forms; and the one serious difficulty that I see in including it definitely in the genus *Polydora* is that all the segments appear to bear normal short permanent capillary setae, *the fifth segment bearing just as large a tuft as the others.* However, as in many species of *Polydora*, there is a small tuft of capillary setae on the fifth segment in addition to the special stout setae, I think it probable that these larvae really do belong to the genus *Polydora*, for they bear gastrotrochs on segments 5, 7, 10 (*not* regularly alternate) just as in both species of Port Erin Polydora larvae, and the stellate patches of dense black pigment appear to be found exclusively in *Polydora* larvae. All known larvae of Polydora (six distinct species) possess patches of dense black pigment, and in at least four of these (Agassiz's larva of *P. ciliata*, loc. cit.; Andrews' larva of *P. commensalis*, 1891; one species of Häcker's *Polydora* larvae, 1898; and *Polydora A* of the present paper) they are large and ramified, as in Claparède's larvae, whilst in the remaining two species (one of Häcker's species of *Polydora* larvae, 1898; and *Polydora B* of the present paper) they are small, unbranched, and less definite in outline and arrangement.

Differences in the shape and arrangement of the large ramified pigment areas, and in the disposition of the gills show that Claparède's larva cannot, however, be of the same species as Agassiz's, and Leschke (1903: pp. 118-121; Pl. VI., figs. 1-6), who has described the development of *P. ciliata* from the egg, states that the larva of this species resembles those described by Agassiz. The early stages described by Leschke, moreover, differ markedly from those described by Claparède, in that the Trochophore bears no setae at all, a stage with the rudiments of three intertrochal segments (Leschke, loc. cit.: Pl. VI., fig. 4) bearing short setae, which only reach their full dimensions in the stage with three completely developed segments (loc. cit.: Pl. VI., fig. 5). Claparède himself accepted Agassiz's removal of his "*Leucodora*" larva from the genus *Polydora* (=*Leucodora*), and in conjunction with Mecznikow described another larva (1869: p. 175; Pl. XII., fig. 3) as that of *Polydora*. But the difference between this larva and Agassiz's is far greater than that between his original "Leucodora" larva and the latter; and a comparison between his figure of it, and Pl. IV., figs. 41, 42, and 43A of the present paper will prove at once that it is really the larva of *Pectinaria*, and that the special setae supposed to belong to the fifth segment are in reality the paleae of this worm, which develop internally in the position shown, and appear fully formed at the anterior end during metamorphosis as described below.

De Saint-Joseph (1894: pp. 63-4; Pl. III, fig. 73) describes a larva which he says is identical with Agassiz's larva of *P. ciliata*. The larvae figured by Cunningham and Ramage (1887: Pl. XXXVII., figs. 2I, 2J) as advanced larvae of *Nerine cirratulus*, differ greatly, as pointed out above (p. 615) from the larva of this species figured by Claparède and Mecznikow; and as nototrochs occur on every segment after the 2nd, and gastrotrochs on the 3rd, 5th, 7th, and 10th segments, exactly as in the Port Erin *Polydora* larvae (those on the 3rd segment being, moreover, rather smaller than the rest, as in the Port Erin larvae), it is likely that these also belong to a species of *Polydora*.

MAGELONIDÆ.

Magelona (Pl. III., fig. 39). Nectosoma.—The nectosoma stages of *Magelona* have been fully described by Claparède (1863: pp. 74-77; Pl. X., figs. 9-14; Pl. XI., figs. 1-2), and subsequently—under the name *Prionospio tenuis*—by Fewkes (1885: pp. 167-172; Pl. I.); that Fewkes' larvae belong to the genus *Magelona* and not to *Prionospio* has been pointed out by Giard (1886: "Sur le dévelopment de *Magelona papillicornis*"; Bull. Sci. du Nord, XVII., p. 98). McIntosh has also examined some stages in the development of this larva (1894: pp. 66-71; Pl. VIII., figs. 1-3). The youngest stages known appear to have been described by Claparède only. On Pl. X. (fig. 9) he figures a larva about 1,000μ in length, the mouth is wide and occupies the whole of the extreme front end of the head; it is surrounded by long cilia, and the ventral lip is deeply cleft. A tuft of long cilia occurs a little in front of each of the pair of bunches of long provisional setae with which the first segment is armed. The first 19 segments each carry a ventral band of cilia near their posterior margins, and are followed by three atrochal segments, and the anal segment with a very strong band of cilia. No tentacles have yet appeared, and setae are confined to the first segment.

The earliest stage seen by Fewkes was 2000-3000μ in length, and in it all the cilia appear to have atrophied. Very long, slender tentacles, covered with spine-like papillae have appeared by this time, and in addition to the very long setae of the first segment, somewhat shorter ones are present on the remaining segments with the exception of a few at the posterior end which never develop any provisional setae at all. The youngest larva from Port Erin is in this stage: it is probably contracted, and is only 1,500μ in length and 150μ in breadth; the head is rounded in front and bears a pair of tentacles about equal to the body in length, but only 50μ in breadth. Two regions can be recognised in the tentacles: a short proximal part, 100μ long, which stains rather deeply, and a long distal part with very slight affinities for borax-carmine. The latter is a purely larval structure, and is shed after the former has reached a length of 150μ. and has begun to show the characteristic papillate appearance of its anterior surface. These papillae on the permanent part of the tentacle are thick and fleshy, differing markedly from the spine-like processes that are scattered over the purely larval region.

During this time the long provisional setae of the first segment reach a length of 1,000μ, and many of those of the nine succeeding segments are shed and replaced by dorsal and ventral tufts of shorter permanent ones. These ten segments—not eight as in Claparède's larvae (loc. cit.: p. 76; Pl. X., fig. 12), or nine as in the adult form described by McIntosh (1878: pp. 402-3) form a distinct anterior region of the body. A middle region, composed of four (sometimes five) segments, retains the provisional setae for a longer period (see Pl. III., fig. 39), and crotchets instead of capillary setae ultimately replace them; the neuropodial crotchets appear before the notopodial in this region. The remaining segments form a posterior part of the body in which no provisional setae develop. At about the time of the appearance of the neuropodial crotchets of the middle region, both neuropodial and notopodial crotchets appear in the posterior part.

The posterior region is terminated by a conical caudal appendage, situated dorsally, which seems to have been overlooked by Fewkes but is described by Claparède (loc. cit. p. 76; Pl. X., fig. 14). The last "segment" in Fewkes' figs. 10, 11, 13, probably represents this appendage, being devoid of parapodia. None of the Port Erin specimens show the broad terminal "segment" of Fewkes' figs. 12, 12a, perhaps because they are not old enough. The anus opens ventrally on the last segment.

In Fewkes' larvae *three* crotchets "arise from the dorsal region of the parapodium. In addition to these appendages the posterior body segments also bear on a ventral elevation smooth spines similar to those on the anterior and middle regions" (loc. cit. p. 171). In balsam-preparations of the Port Erin larvae I have been unable to find any capillary setae on either the middle or posterior body-regions. Fewkes also found, in the case of the provisional setae, that those of the anterior region (except the first segment) were completely lost at a comparatively early stage, and in this his observations are in agreement with those of Claparède. Specimens from Port Erin, however, show these setae even after the loss of the larval tentacles. This is probably another example of the great variability in the time at which such phenomena occur in Spioniform larvae (see above, pp. 609 and 610), a fact noted by McIntosh in this particular connection (1894: p. 69).

A "Magelona-like" larva has been described from the Cape Verde Islands by Häcker (1898: pp. 20-23; Pl. II., fig. 19). The larval tentacles of this form each bear a prominent swelling about one-third of the way along towards their distal ends, which extend beyond the posterior end of the body when held straight out, and even then are not as long as the setae of the first segment.

CHÆTOPTERIDÆ (Pl. IV., figs. 12-14).

A mesotrochal larva, probably that of *Chaetopterus*, is fairly plentiful in the Port Erin plankton during July. In life it is covered all over with short (10μ) cilia, and bears first one and then two bands of longer (100μ) cilia; the head bears three pairs of small opaque red eye-spots, an anterior pair placed near together on either side of the middle line, and two closely approximated posterior pairs placed one behind the other at the sides of the head. Long rigid cilia occur (singly ?) between the two anterior eyes and in other places upon the head, but their distribution is very hard to determine on account of opacity. The body is terminated at the posterior end by a caudal appendage whose shape and movements show a striking resemblance to the "foot" of a Rotifer; this is almost always completely retracted in fixed specimens.

Trochophore.—The youngest stages found are 400μ by 300μ in size when contracted (Pl. IV., fig. 12). The mouth is very large, and is overhung in front by the broad hood-like head and bounded behind by a deeply cleft under-lip. It leads through a funnel-shaped oesophagus (directed backwards) into the stomach, and thence into a short, broad and very thin-walled rectum; both these last already contain diatoms and other food-material from the exterior.

A single band of strong (100μ) cilia is present encircling the larva in the plane of the pylorus; this "mesotroch" is characteristic of larvae of the Chaetopteridae.

Metatrochophore. A second band of powerful (100μ) cilia appears a little behind the first, and shortly after this the region between the mouth and the anterior of these bands becomes marked out into segments by the appearance of successive rows of setae, the anterior setae of each row being short and the succeeding ones each a little longer than the one in front (Pl. IV., fig. 13); in the oldest specimen seen too ($1,150\mu$ by 900μ in size when contracted), the special stout setae of the fourth chaetigerous segment are visible embedded in the body-wall. Between the second band of powerful cilia and the caudal appendage deeply-staining segments are formed. Whilst segmentation is in progress the deeply-cleft under-lip grows more rapidly than the prostomium (compare Pl. IV., figs. 12 and 13) till in the oldest specimen seen (Pl. IV., fig. 14) the mouth is terminal, and being of enormous size occupies the whole of the anterior end of the body. In this specimen a pair of tentacles have begun to develop on the dorsal surface of the head, a short distance from its anterior margin.

In specimens of these later stages, which were examined alive, the long rigid cilium, situated close to the anterior margin of the prostomium, between the anterior eyes, appeared to be feeling about in front of the animal as it moved along. One of these larvae, also, was seen to take into its mouth a good-sized copepod and swallow it; whilst a Ceratium and a sponge-spicule entered the mouth of another, but were rejected. It was further noticed that the bands of powerful cilia were broken in the mid-ventral line and that a groove, apparently ciliated exactly like the general surface of the body, extended forwards from the anus towards the mouth through the gaps thus left. From Wilson's account of the larvae of *Chaetopterus pergamentaceus* (1882: pp. 285-6) it would appear that this is the case also in the early stage, when only the first of the two bands of powerful cilia is present; but none of these early larvae have been examined alive at Port Erin.

Further stages in the development of these larvae than that shown in Pl. IV., fig. 14, I was unable to follow. Béraneck (1894), however, has described the later stages of another species of *Chaetopterus*. The earliest stage observed by this author corresponds roughly to the latest stage described above, but differs from it in that the segments of the anterior body region (i.e., the part in front of the first mesotroch) are already indicated in the outlines of the body, but as yet bear no setae. Subsequently the region in front of the anterior mesotroch is shown to give rise to the anterior region of the body, the segment between the two mesotrochs to the segment bearing the wing-like lateral processes, and the remainder to the rest of the middle and the whole of the posterior body-regions of the adult.

The development of *Chaetopterus* from the ovum to the Trochophore has been fully worked out for *Chaetopterus variopedatus*, Ren. (*pergamentaceus*, Cuv.) by Wilson (1882). He notes the existence of a temporary mesotroch (anterior to and developed earlier than that retained in the latest trochophore stages), and immediately behind this a pair of lateral flagella, which also disappear during the trochophore stage; these temporary structures appear in the earliest Trochophores (one to five days), which show a ventral mouth of normal size leading through an oesophagus anteriorly to the stomach as in the Trochophores of less modified worms. Apical and anal tufts of long cilia are present, the latter being carried backwards on the end of the caudal appendage as this develops.

Subsequently the mouth is enlarged and pushed forwards so that the now funnel-shaped oesophagus passes backwards instead of forwards, to open into the stomach, which on the third day comes to open to the exterior through a short rectum exactly as in the Port Erin form.

Wilson also describes (loc. cit., pp. 286-8; Pl. XXII., figs. 85-88; Pl. XXIII., fig. 9) a few later stages of a larva provisionally referred by him to the genus *Spiochaetopterus*. The larvae of *Telepsavus* and ? *Phyllochaetopterus* are described by Claparède and Mecznikow (1869: pp. 178-182; Pl. XIV., figs. 1-1E, and 2) and by Fewkes (1885: pp. 177-180; Pl. III., figs. 5-19). The caudal appendage is present in both forms; only one mesotroch is present throughout the development of the former.

III.—TEREBELLIFORMIA.

Amphictenidæ.

Pectinaria (Pl. IV., figs. 40-47).—Metatrochophore I.—No Trochophore of this worm has been seen, but the youngest Metatrochophore (250μ by 190μ) shows little trace of segmentation and can be only just beyond the trochophore stage. It is ovate in shape, the posterior end being slightly narrower than the anterior. The prostomium is rounded and covered with black pigment spots which tend to be aggregated into a band encircling it just in front of the prototroch, which is slightly raised above the mouth (fig. 40). Segmentation is only indicated by unilateral transverse rows of pigment spots on the posterior part of the larva. The anus is bordered dorsally and laterally by a horseshoe-shaped ridge thickly covered with pigment spots.

A slightly older larva (300μ by 200μ) is shown in Pl. IV., fig. 40; this differs from the previous stage in that there is now a marked enlargement of the body immediately behind the prototroch: the cells in this region appear to contain large vacuoles.

In life the cilia are arranged as shown in Pl. IV., fig. 40, and a pair of opaque reddish-brown eye-spots are present on the head (Pl. IV., fig. 40). The cilia of the prototroch are 75μ long, and are very powerful: at the apex, or slightly dorsal to it, is a tuft of cilia. The mouth is bordered by large lips, which differ from those of the Spioniform larvae in that they are situated entirely behind the prototroch, as in the larvae of *Polynoë*; and from those of the larva of *Polynoë* in that they close in the mouth laterally as well as on the anterior side. These lips are bordered and covered on the inner side with cilia 20μ long; and at the posterior angle of the mouth in the mid-ventral line there is a tuft of 40μ cilia (see Pl. IV., fig. 47c, showing the lips of an older larva, from which these measurements were actually taken). The lips are almost always retracted in preserved specimens, though the larva shown in Pl. IV., fig. 41, has died with them extended, and with the anterior part of the oesophagus protruded beyond them; the tumid posterior wall of the protruded oesophagus in this specimen is much vacuolated; the ridge encircling the organ probably represents the margin of the lips when normally extended. In life the lips are almost invariably held extended to an even greater extent than is shown in Pl. IV., fig. 40,* and give the larva a very characteristic appearance that is well brought out in Willemoes-Suhm's figure of an advanced larva (1871: Pl. XXXI., fig. 11), which, however, he has neither identified nor described. The anus is closely surrounded by extremely delicate short cilia; ventral to the anus is a

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* Subsequent observations suggest that in full extension a trough-shaped structure is protruded beyond the lips, but on account of its extreme sensitiveness I have been unable to examine it very closely.

little spherical projection (Pl. IV., fig. 47; *Sph.*) situated between the arms of the horseshoe-shaped anal ridge (*An. R.*), and immediately in front of this projection is a tuft of 20μ cilia (*T.C. Ntr.*) from which a neurotroch (*Ntr.*) of 8μ cilia extends forwards, to end a little behind the mouth in a short transverse row of 10μ cilia (Pl. IV., fig. 47c; *C. trans.*). The telotroch is situated anterior to the posterior end of the neurotroch. The larva grows considerably both in length and in breadth, and food material from the exterior may be found in the stomach. When the lips are contracted, larvae of the age of that shown in Pl. IV., fig. 41, are about 450μ long by 300μ maximum breadth. The paleae, or large setae that project forwards from the anterior end of the adult, may be seen developing in the dorsal body-wall on each side of these larvae, with their pointed distal extremities close behind the preoral band and their bases several segments further back. The horseshoe-shaped ridge on the posterior surface of the anal segment is considerably enlarged; as before it is covered with pigment spots.

Metatrochophore II.—The setae usually appear at about the period of development of the larva seen in Pl. IV., fig. 41, though one larva with fewer segments than this has setae which have already attained their full length for the larval period (80μ). The body next becomes more elongated; the setae all attain their full (larval) size; and a definite region appears between the last of the chaetigerous segments and the anal segment (Pl. IV., figs. 42 and 43b). This region bears no pigment spots, and shows a very short anterior part, consisting of one segment like those anterior to it, except for the absence of pigment and setae, and a longer (100μ) posterior part—the rudiment of the scapha—which already shows traces of lateral processes in the specimen from which fig. 43 was drawn. The large paleae become more conspicuous; their position relative to the segments is as before, the kite-shaped area which they occupy having diagonal measurements of 300μ by 90μ. They are arranged as shown in Pl. IV., fig. 43a; four lie close together throughout their whole length, and have their distal extremities curled round the point of a short straight fifth spine: the sixth is very hard to distinguish—in fact, it is very doubtful whether it is really present at all yet—and is therefore indicated by dotted lines only. This stage is the one figured by Willemoes-Suhm (see above), and is much more common than the others, whence it may be inferred that it marks a period of quiescence preparatory to metamorphosis.

Metamorphosis.—From the fact that during my 1907 visit to Port Erin I only obtained a single specimen intermediate between the last-mentioned stage, and the secretion of the tube by an almost fully developed worm, it seemed probable that a rapid metamorphosis occurred at this point in the life-history. This single specimen is shown in Pl. IV., fig. 44. The umbrella is much reduced in size, and appears somewhat shrunken: the ciliated band is raised above the mouth on a pair of prominences; the oesophagus appears to be partially everted. The paleae have broken through the dorsal body-wall at about the middle of the first segment, as indicated by the lines of pigment-spots, the larva being now much broader here than in the plane of the prototroch; the presence of the sixth of the paleae is still doubtful. Lateral to the groups of paleae a pair of short tentacles (80μ by 15μ) are now to be seen (Pl. IV., fig. 44: *T. lat.*).

The scapha appears in profile as a region devoid of pigment and segmentation: the cilia of the telotroch are greatly reduced possibly absent; the anal ridge, however, is still fully developed and covered with black pigment spots. No setae, except the paleae, can be seen in this specimen, but no doubt this is due to their being placed, in the mounted and rather deeply stained specimen, so as to occupy a position above the body, or to their having been shed during fixation; I have therefore inserted them in the figure in the position they occupy in larvae during the quiescent period immediately before metamorphosis.

During my visit to Port Erin in 1908 I had the good fortune to see something of the metamorphosis in progress in a living larva. From a plankton collection taken on August 1, a number of Polychaet larvae were picked out as usual, and placed in fresh sea water in a crystallising dish from which they were taken for examination one by one. Amongst these was an advanced Metatrochophore of *Pectinaria*, which towards the end of the morning presented a slightly abnormal appearance, giving me the impression (when seen under a low power of the microscope) that it would not live much longer, and would even then be of no use for detailed examination; this was not at all surprising, for the larvae usually showed such signs of deterioration after five or six hours, and even sooner. However, the larva was allowed to remain in the crystallising dish, and when I again saw it under the microscope, after an interval of about half an hour, I found that its previous abnormal appearance had been due to the fact that it had been in an early stage of the metamorphosis which it had now almost completed. The metamorphosis was, indeed, so far advanced that I decided to fix the larva at once, and so only gave it a cursory examination with the low power during life. This larva is shown in Pl. IV., fig. 15, from which it will be seen that the paleae now project forwards as in the adult, and that the umbrella is much further reduced than in the earlier metamorphosis stage described above; in fact the creature bears a closer resemblance to the adult than to the larval form. A median tentacle 40μ long has appeared at the anterior extremity of the prostomium—the apical pole of the larva. A little behind this on the ventral surface are a pair of laterally compressed lobes (Pl. IV., fig. 45; *L.*): these are probably developed from the lobes above the mouth over which the prototroch extends in the previous larva; their identification is rendered a little uncertain however by the fact that in the present larva the prototroch, which was only visible during life, seemed to be situated immediately *behind* them. The cilia of the prototroch were no longer active—it is of course possible, though I think not probable, that this was entirely due to the length of time that the larva had been kept in confinement; the creature was quite active otherwise, and twisted backwards and forwards very vigorously.

The lips, usually so conspicuous in the living larva, were not seen at all in this specimen. The black pigment spots of the larva have disappeared completely from the prostomium, and to a considerable extent from the body as well (compare Pl. IV., figs. 42-44 with figs. 45-46). A pair of tentacles is present lateral to the paleae. Uncini are just distinguishable in the body-wall. The creature had not begun to construct its tube when killed.

Tube-secreting stage.—Several little worms in their tubes were taken at the surface, and one of these is shown in Pl. IV., fig. 46. The pair of ventral outgrowths of the head seen in the second of the metamorphosis stages described above are held, in fixed specimens, close against the body (Pl. IV., fig. 46; *L.*), but can be extended out from the body during life.

The extent to which the larval rows of black pigment-spots are retained varies considerably in the different specimens, they being in some confined to a patch on each side of every segment (as in fig. 46), and in others quite as fully developed as in the second metamorphosis stage described above: pigment-spots are now also irregularly scattered over the anterior part of the ventral surface, and a very variable number of larger (20-50μ diameter) patches are present on the dorsal surface of the anterior segments. One pair of eye-spots may be seen in living specimens.

There is no longer any trace of the prototroch, unless it is represented by two short rows of small cilia that are situated one on each side of the head. The short straight capillaries of the larva persist as the dorsal setae of the tubicolous form; ventral uncini are also present. The scapha (Pl. IV., fig. 46; *Sc.*) bears a single median posterior process and a pair of lateral anterior ones; it appears to retain a faint trace of the telotroch in the form of a girdle of faintly-staining cells near its posterior border (Pl. IV., fig. 46; *Ttr.*?); the anal ridge with its pigment-spots has atrophied.

The tube (1,200μ long) is much longer than the worm (800μ long in the fixed condition, the paleae projecting to an additional distance of 150μ); at their widest part both worm and tube are 250μ broad. The walls of the tube are very thin and transparent, and only the most minute particles of foreign matter are attached to it, and these only in very small quantities.

The development of *Pectinaria* has apparently been described by Bobretzky (Verh. Ges. d. Naturf. Kiew: Vol. VIII.; 1873) but I have not been able to refer to his paper. Leschke (1903: p. 127; Pl. VI., fig. 13) also briefly describes this and figures an advanced Metatrochophore with its lips extended. Claparède and

Mecznikow describe and figure a similar larva, but refer it to the Spioniform genus Polydora (1869: p. 175; Pl. XII., fig. 3: see above p. 641). Willemoes-Suhm figures another such larva (1871: Pl. XXXI., fig. 11), but does not identify or describe it.

CONCLUSION.

In the present limited state of our knowledge of Polychaet larvae it would be futile to attempt to give a diagnosis of the larval characteristics of the different families and genera of Polychaets. In the vast majority of genera the early stages are quite unknown, and where anything *is* known of them it is confined to a very small proportion of the known adult species. A table for the identification of the above described species from Port Erin, however, will form a convenient summary of their most useful characters for systematic purposes; and *wherever possible* the particular characters given will be those that at present seem most likely to be of general application.

As I have only been able to describe the trochophore stage in any detail in two of these larvae, and as the latest pelagic stages of the Nereidiformia are characterised chiefly by the characters of the adult, the following table will deal specially with the metatrochophore stage, or in the Spioniformia with this and the nectosoma stage; references to any special characters of the other known stages will be enclosed in brackets.

It should be noted that many of the characteristics mentioned are intimately connected, or even identical with those of the adult worm, and therefore cannot be used as embryological evidence, independent of adult structure, for or against any particular scheme of Polychaet classification.

TABLE FOR THE IDENTIFICATION OF PELAGIC POLYCHAET (METATROCHOPHORE) LARVAE OCCURRING IN PORT ERIN BAY DURING JULY.*

1. Larva mesotrochal: **Chaetopteridae.**

Larva cylindrical, with four well-developed ciliated bands: † **? Syllidae.**

Larva not as above: **(2)**

2. Long provisional capillary setae present; body usually slender: (**"Metachaetae,"** Clap.). **(6)**

Prostomium and anal segment bearing numerous black pigment-spots; each intertrochal segment with a girdle of similar spots; body compact; no provisional setae: ‡ **Pectinaria.**

Body usually compact; neither provisional setae nor numerous black pigment spots: (**Nereidiformia**). **(3)**

3. Prototroch replaced by a broad band of cilia: § **Eunicidae.**

True prototroch present: **(4)**

4. Body very compact; setae strongly toothed; rudiments of elytra present; (Trochophore monotrochal and characterised by overhanging upper lip, and presence of simple akrotroch, neurotroch, and *circlet* of apical cilia): **Polynoidae.**

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* A few species have been found which are not described above, or included in this table. They are all of rare occurrence, and the table will, I believe, be found sufficient to refer them to their systematic position with as much precision as is possible in the absence of a sufficient description.

† Later stages characterised chiefly, according to Häcker, by a stout sickle-shaped bristle borne by each parapodium.

‡ This form remains pelagic for a short time when tubicolous after a rapid metamorphosis.

§ This character will not serve to distinguish Hacker's later stage of a similar larva in which adult characteristics are appearing.

Two pairs of transparent conical cephalic tentacles present at the anterior end of the prostomium; neurotroch, and **T**-shaped akrotroch with "hook" of cilia present at first; (Trochophore characterised by its great contractility, and by the above form of the akrotroch): (**Phyllodocidae**.) (5)

Parapodia uniramous; rami long except in very early stage; each with compound setae and at least one simple smooth seta (in many Syllids this last distinction would almost certainly not apply): **Syllidae**. (species distinguished by their setae, see Pl. I., figs. 2-4.)

Dorsal and ventral rami of parapodia very short, with smooth and frilled capillary setae; body somewhat elongated: **Nephthydidae**.

5. Three pairs of tentacular cirri; larva rather small: **Phyllodocid A**

Four pairs of tentacular cirri; larva large: **Phyllodocid B**.

No tentacular cirri; larva large: **Phyllodocid C**.

6. Larva with ventral mouth bordered by large lateral lips enclosing a "vestibule" and causing a ventral break in the continuity of the prototroch; a pair of simple tentacles appear close behind the prototroch in the later stages; (the Trochophore of *Nerine cirratulus* is enclosed in a vitelline membrane characteristic of the species): (7)

Larva with anterior broad chaetigerous, middle narrow chaetigerous, and posterior narrow achaetigerous body-regions; a pair of tentacles present, ultimately papillate on the anterior surface, and each in early stages continued into a remarkably long larval tentacle set with spine-like papillae; devoid of cilia; (the earliest stages known, according to Claparède, have a wide anterior gaping mouth, and are polytrochal): **Magelona.**

7. Nototrochs present on all segments, gastrotrochs on segments 5, 7, 10, 13, 15, 17, etc.; much black pigment; (the more advanced larvae show the enlargement and special setae of the 5th segment): **(Polydoridae.)** (8)

Distribution of cilia not as above; or pigment absent: **(Spionidae.)** (9)

8. Ramified stellate patches of intense black pigment present: **Polydora A.**

No such patches present; black pigment arranged in discontinuous transverse bands: **Polydora B.**

9. Larva very small, with three pairs of black eye-spots; provisional setae of 1st segment twice the length of the body: **Spio.**

Larva very small, with one pair of eye-spots which disappear in spirit; provisional setae shorter than the last: **Spionid C.**

Larva very large and transparent; in later stages notopodia and neuropodia of segments 7-11 are decidedly longer than those of the other segments:	**Spionid A**
Larva decidedly smaller than the last and slightly more opaque; segments as long as they are broad; (in the latest pelagic stages branchiae begin to develop at the anterior end):	**Spionid B**.
Larva broad and rather short; head produced forwards into a very characteristic "snout" which disappears in fixed specimens; provisional setae very stout and decidedly curved:	**Spionid D**.

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EXPLANATION OF PLATES.

Except where otherwise stated, the figures have been drawn in outline with the aid of a camera-lucida from stained specimens mounted in Canada-balsam; and modifications and additions have then been inserted from rough sketches of the living larvae, made in the laboratory at Port Erin.

Reference Letters.

Akr. = Akrotroch.
An. Sty. = Anal style.
Ant. = Anterior mass of deeply staining tissue (brain rudiment).
C. ap. = Apical cilia.
C. or. = Oral cilia.
Cir. i., ii., iii. = Tentacular cirri of segments one, two and three.
E. = Eye.
M. = Mouth.
Ntr. = Neurotroch.
Ph. = Pharynx, or its rudiments.
Post. = Posterior masses of deeply staining tissue (first tissue to show signs of segmentation).
Pr. = Prostomium.
Ptr. = Prototroch.
S. = Setae.
T. = Tentacle.
Ttr. = Telotroch.
i., ii., iii., etc. = Primary segments number one, two, three, etc.

N.B. It will be noticed that figures 1 to 14 have been distributed, a few at the foot of each of the four plates.

Plate I.

Fig. 1. *Syllid A.*—Metatrochophore, dorsal aspect. × 75. The eye-spots and cilia as seen during life (and as shown here) have only been seen in a more advanced specimen.

Fig. 2. *Syllid A.*—Setae: (*A*) Simple seta; (*B*) Compound seta.

Fig. 3. *Syllid B.*—Setae (*A* and *B*) Simple setae; (*C*) Compound seta.

Fig. 4. *Syllid C.*—Setae. (*A*) Simple seta; (*B*) Compound seta.

Fig. 5. ? *Syllid.*—Optical section. × 75. (From a mounted specimen only.)

Fig. 15. *Polynoë.*—Trochophore seen from the right side. × 75. *C.*, long motionless cilia; *Caec.*, dorsal lobe of stomach. *T. med.*, median tentacle (rudiment).

Fig. 15a. Outline of ventral surface of the same larva as fig. 15 to show more clearly the distribution of the cilia.

Fig. 16. *Polynoë.*—Metatrochophore, dorsal aspect. × 75. *El.*, elytra.

Fig. 17. *Polynoë.*—More advanced Metatrochophore, ventral aspect. × 75. *El.*, elytron. *T. med.*, median tentacle (rudiment).

Fig. 18. *Polynoë.*—Head of Nectochaeta, dorsal aspect. × 75. *T. lat.*, lateral tentacle; *T. med.*, median tentacle.

Fig. 19. *Polynoë.*—Anterior end of one of the most advanced pelagic stages, dorsal aspect. × 75. *El.*, elytron., *J.*, jaws; *P.*, palp; *T. lat.*, lateral tentacle; *T. med.*, median tentacle.

Fig. 20 A and B. Two views of a seta from the ventral tuft of a *Polynoë* larvae.

Fig. 21. *Eunicid* larva. × 75.

PLATE II.

Fig. 6. *Phyllodocid A.*—Trochophore; seen from the right side. × 75. *Akr.*, **T**-shape akrotroch; *Med. Hk.*, its median "hook" of cilia; *Ntr.*, Neurotroch—expanded laterally to cover a large area in the particular region indicated by the letters.

Fig. 7. *Phyllodocid A.*—Anterior end of Nectochaeta, dorsal aspect. × 75.

Fig. 7a. *Phyllodocid A.*—Seta.

Fig. 8. *Phyllodocid B.*—Metatrochophore, ventral aspect. × 75. (From a mounted specimen only.)

Fig. 9. *Phyllodocid B.*—Seta.

Fig. 22. *Spionid A.*—Anterior end of one of the most advanced larvae seen, dorsal aspect. × 60. (From a mounted specimen only.)

Fig. 23. *Spionid A.*—First parapodium of the left side of the above larva. × 80 (diagrammatic; the full length of the long notopodial provisional setae is not shown).

Fig. 24. *Spionid A.*—Second to third parapodium of the left side of the above larva. × 80 (diagrammatic).

Fig. 25. *Spionid A.*—Left parapodium of one of the 4th-6th segments of the above larva. × 80 (diagrammatic*).

Fig. 26. *Spionid A.*—Left parapodium of one of the 7th-11th segments of the above larva. × 80 (diagrammatic*).

Fig. 27. *Spionid A.*—Parapodium from a larva in the stage before the differentiation of the parapodia of segments 7-11.

Fig. 28. *Polydora A.*—Nectosoma, dorsal aspect. × 75; stage at which the tentacles first become visible—in the figure they are obscured by the prototroch. The seta and the cilia have been omitted in part in order that the pigmentation may be more clearly seen.

Fig. 29. *Polydora A.*—Anterior end of a more advanced Nectosoma, dorsal aspect. × 75. (From a mounted specimen only.)

Fig. 30. *Polydora A.*—Setae. (*A*) Left side of the specially modified 5th segment with its setae; dorsal aspect; (*B*) Crotchet (hooded ?); more highly magnified than (*A*).

Fig. 31. ? *Polydora.*—Seta.

Fig. 32. *Polydora B.*—A segment from about half way along the body, to show the arrangement of the pigment; setae and cilia not shown.

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* The spherical projection between the rami is not present on all of these parapodia, and its outline has, therefore, been indicated in figs. 25 and 26 by a dotted line.

Plate III.

Fig. 10. *Nephthys.*—Metatrochophore, ventral aspect. × 75. (From a mounted specimen only.)

Fig. 11. *Nephthys.*—Setae. (*A*) Frilled seta; (*B*) Smooth seta.

Fig. 33. *Spionid B.*—Nectosoma, anterior end, dorsal aspect. × 75. (From a mounted specimen only). *S. per.*, permanent setae; *S. prov.*, provisional setae.

Fig. 34. Posterior end of the same larva, ventral aspect. × 75.

Fig. 35. *Spionid C.*—Metatrochophore. (From a preserved specimen except for the eyes.) × 75.

Fig. 36. *Spionid D.*—Metatrochophore, fully contracted. × 75. (From a mounted specimen only).

Fig. 37. *Spionid D.* Anterior end of more advanced and well expanded Metatrochophore. × 75. Only the bases of the setae shown. *Pr.*, snout-like anterior prolongation of the prostomium.

Fig. 38. *Spio.*—Metatrochophore. × 75. (From a mounted specimen only.)

Fig. 39. *Magelona.*—Nectosoma which has shed the provisional setae from all segments of the anterior body-region except the first; the larval region of the tentacle of the left side has also been shed; × 75. *S. per. cap.*, permanent capillary setae of the anterior body-region; *S. per. cr.*, crotchets (permanent setae) of the middle and posterior body-regions; *S. prov.*, provisional setae of the first segment and of the middle body-region; *T. larv.*, larval portion of the right tentacle; *T. per.*, permanent portion of the tentacles.

Figs. A. and B. Diagrams of akrotroch of *Phyllodocid C.*—(A) Profile; (B) Surface view. *l.*, lateral extensions; *m.*, median piece; *m. l. c.*, median long cilia; *p. hk.*, paired "hook" of long cilia.

Fig. C. Trochophore of *Nerine cirratulus.* (After Leschke, modified from Cunningham and Ramage).

Plate IV.

Fig. 12. *Chaetopterus.*—Trochophore. Optical section. × 40. (From a mounted specimen only.) *R.*, rectum; *St.*, stomach.

Fig. 13. *Chaetopterus.*—Metatrochophore, ventral aspect. × 40. Fully contracted. *E. ant.*, anterior pair of eyes, immediately in front of which a long rigid cilium is seen; *E. post.*, right eyes of the two closely approximated posterior pairs. *Mtr.* 1 *and* 2. anterior and posterior mesotrochs.

Fig. 14. *Chaetopterus.*—More advanced Metatrochophore than that of fig. 13: dorsal aspect. × 40. (From a mounted specimen only.) *Cd.*, caudal appendage; *S. sp.*, special setae of the fourth segment; *U.-L.*, under-lip.

Fig. 40. *Pectinaria.*—Very early Metatrochophore, from the right side. × 75. *An. R.*, anal ridge.

Fig. 41. *Pectinaria.* More advanced Metatrochophore with oesophagus protruded; from the left side. × 75. (From a mounted specimen only.) *An. R.*, anal ridge: *Oe.*, protruded oesophagus; *Pal.*, developing paleae seen through the body-wall.

Fig. 42. *Pectinaria.*—Metatrochophore almost ready for metamorphosis: ventral aspect. × 75. (From a mounted specimen.) *An. R.*, anal ridge. The prototroch is indicated at the sides; its further course is marked by the absence of pigment except in the region of the mouth, where it could not be followed precisely.

Fig. 43. *Pectinaria.* Parts of the most advanced Metatrochophore seen. (*A*) Paleae as seen through the body-wall. × 120; (*B*) Posterior end, ventral aspect. × 75. To show the rudiment of the scapha (*Sc.*).

Fig. 44. *Pectinaria.* Early metamorphosis stage from the left side. × 75. (From a mounted specimen only). *Pal.*, paleae beginning to project from the body wall; *T. lat.*, lateral tentacles.

Fig. 45. *Pectinaria.*—Later metamorphosis stage; from the left side. × 75. (From a mounted specimen.) *L.*, compressed lobes of the ventral surface; *Pal.*, paleae; *Ptr.*, probable position of the prototroch (visible during life only, and therefore indicated by a dotted line); *Sc.*, scapha; *T. lat.*, lateral tentacle; *T. med.*, median tentacle.

Fig. 46. *Pectinaria.* Tubicolous stage before the commencement of life on the sea-bottom; ventral aspect. × 75. (From a preserved specimen only.) *L.*, compressed lobes of the ventral surface; *Pal.*, paleae; *Sc.*, scapha; *T. lat.* 1 *and* 2, right lateral tentacles (of outer and inner pair respectively); *T. med.*, median tentacle; *Tb.*, tube secreted by the worm; *Ttr* ?, remnant of telotroch ?

Fig. 47. *Pectinaria.*—Parts of the Metatrochophore as seen during life, to show the arrangement of the cilia. (*A*) Anal segment from behind; (*B*) Posterior end from the right side; (*C*) Oral region from the right side; *An.*, anus; *An. R.*, anal ridge; *C. an.*, delicate cilia round the anus; *C. trans.*, transverse row of cilia at the anterior end of the neurotroch; *C. or.*, oral cilia; *Ntr.*, neurotroch; *Ptr.*, prototroch; *Sph.*, spherical prominence immediately behind the posterior end of the neurotroch; *T. C. Ntr.*, tuft of cilia in which the neurotroch terminates; *T. C. or.*, tuft of cilia which marks the posterior boundary of the oral ciliated region; *Ttr.*, telotroch.

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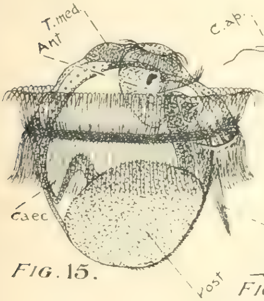

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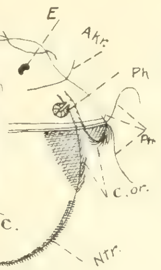

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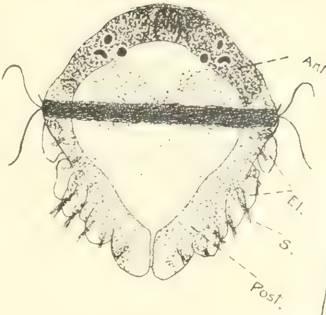
FIG. 16.



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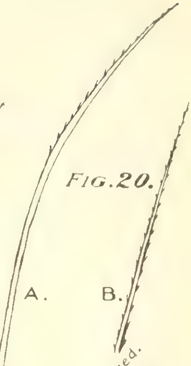

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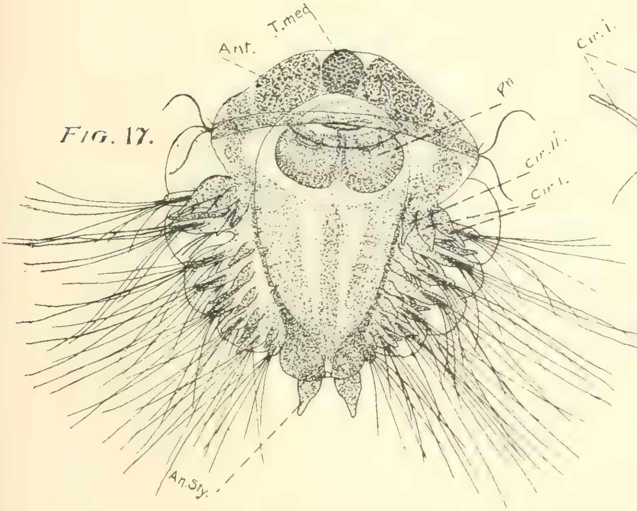

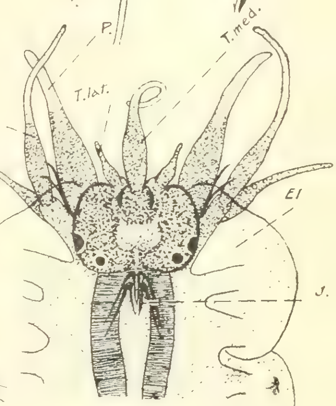

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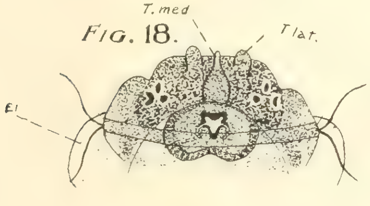

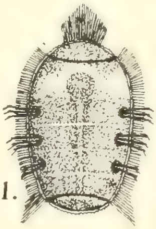

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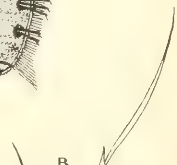

FIG. 3.

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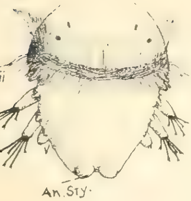

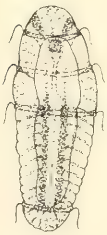

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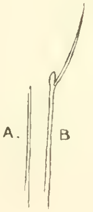

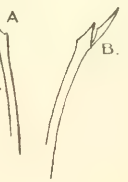

FIG. 2.

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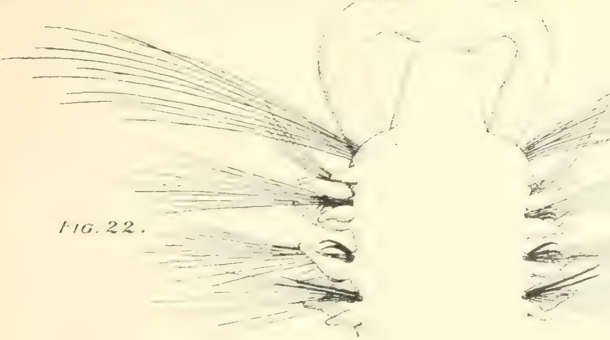
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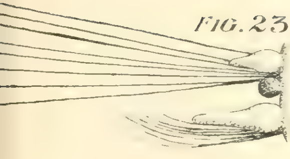
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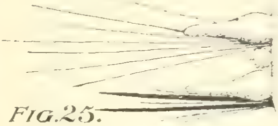
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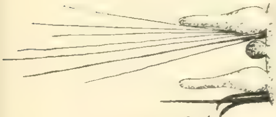
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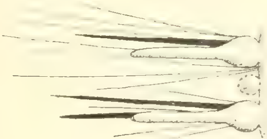
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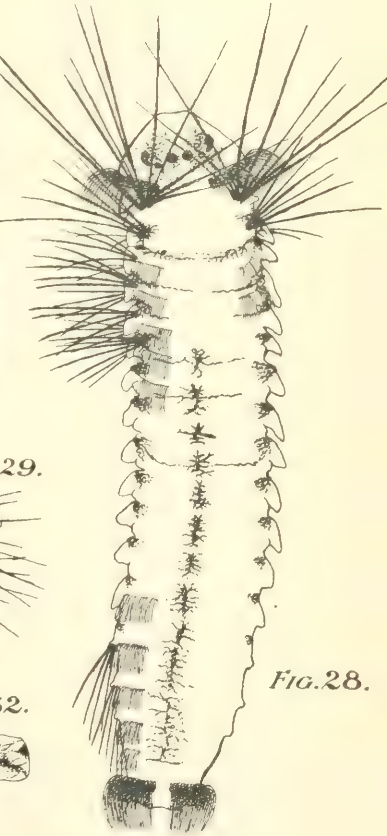
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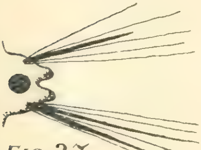
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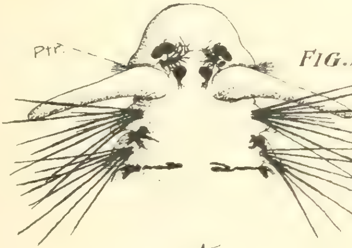

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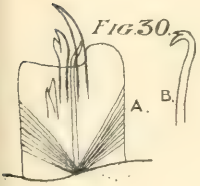

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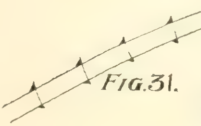
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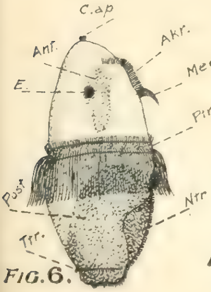

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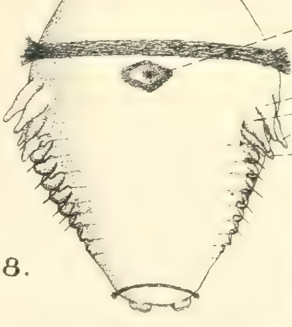
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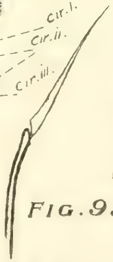
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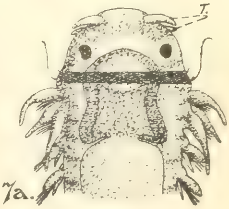

FIG. 7.

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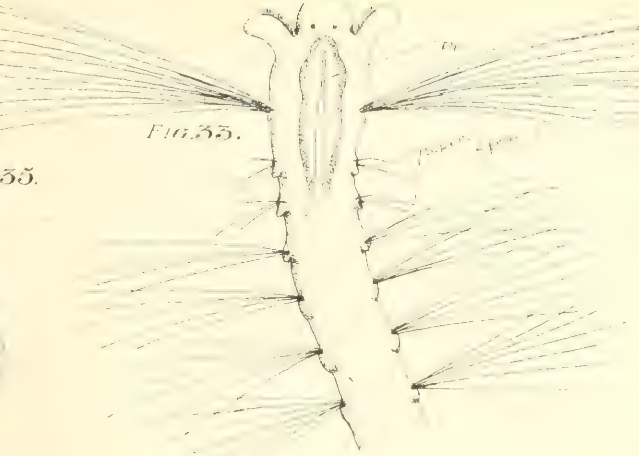

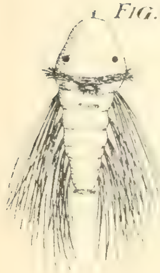

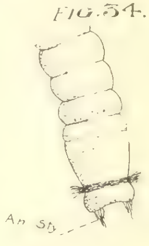

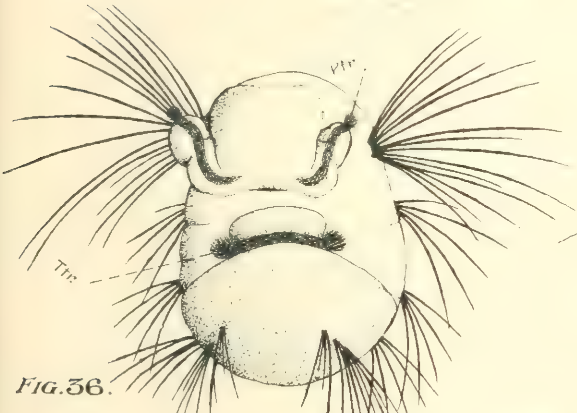

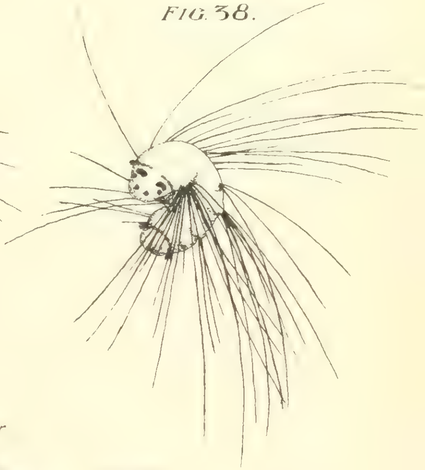

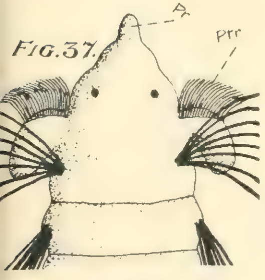

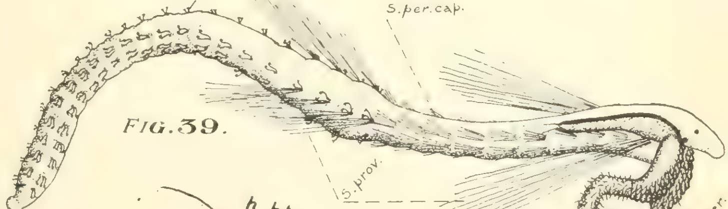

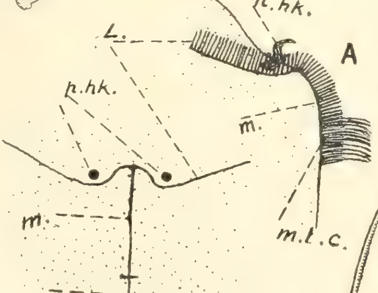

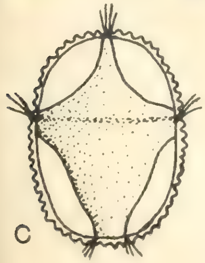

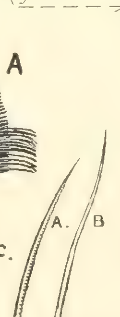

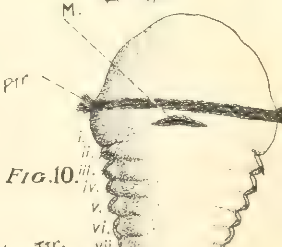

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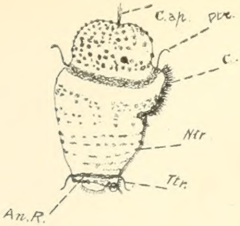
FIG. 40.



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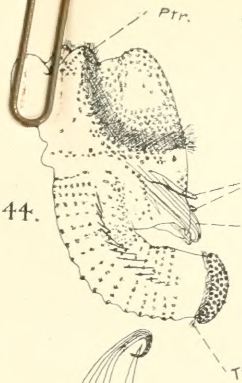

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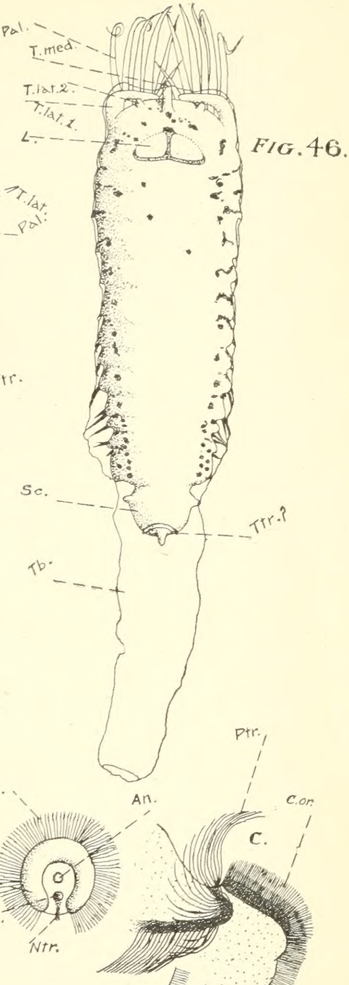

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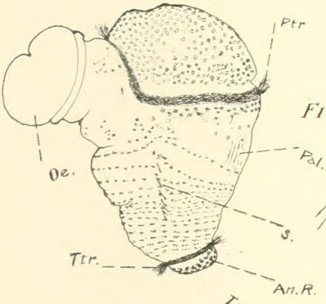

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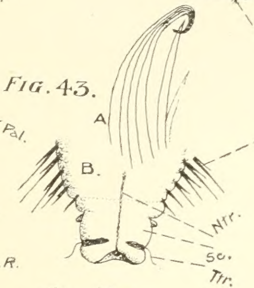

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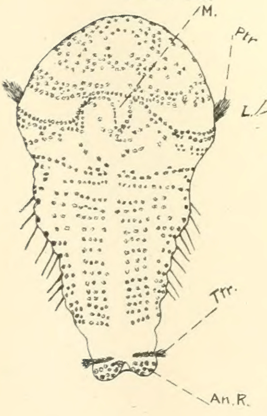

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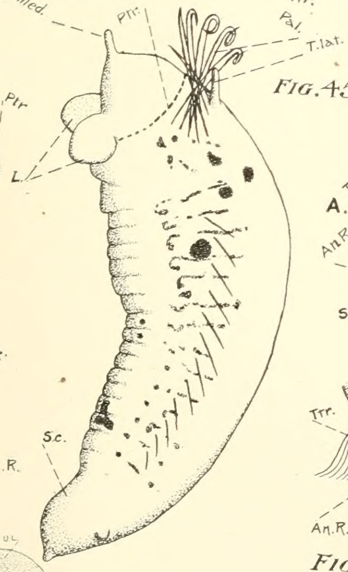

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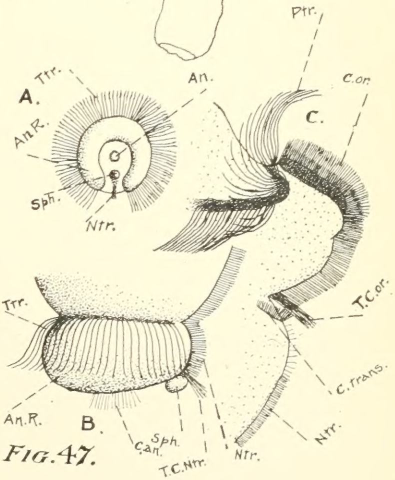

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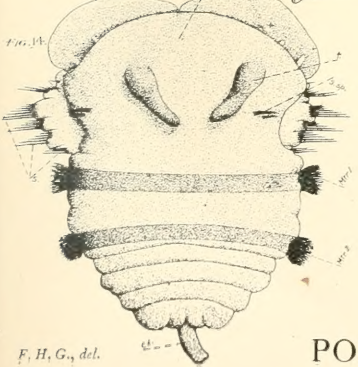

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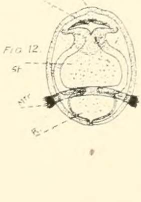

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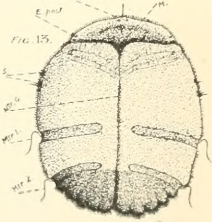

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